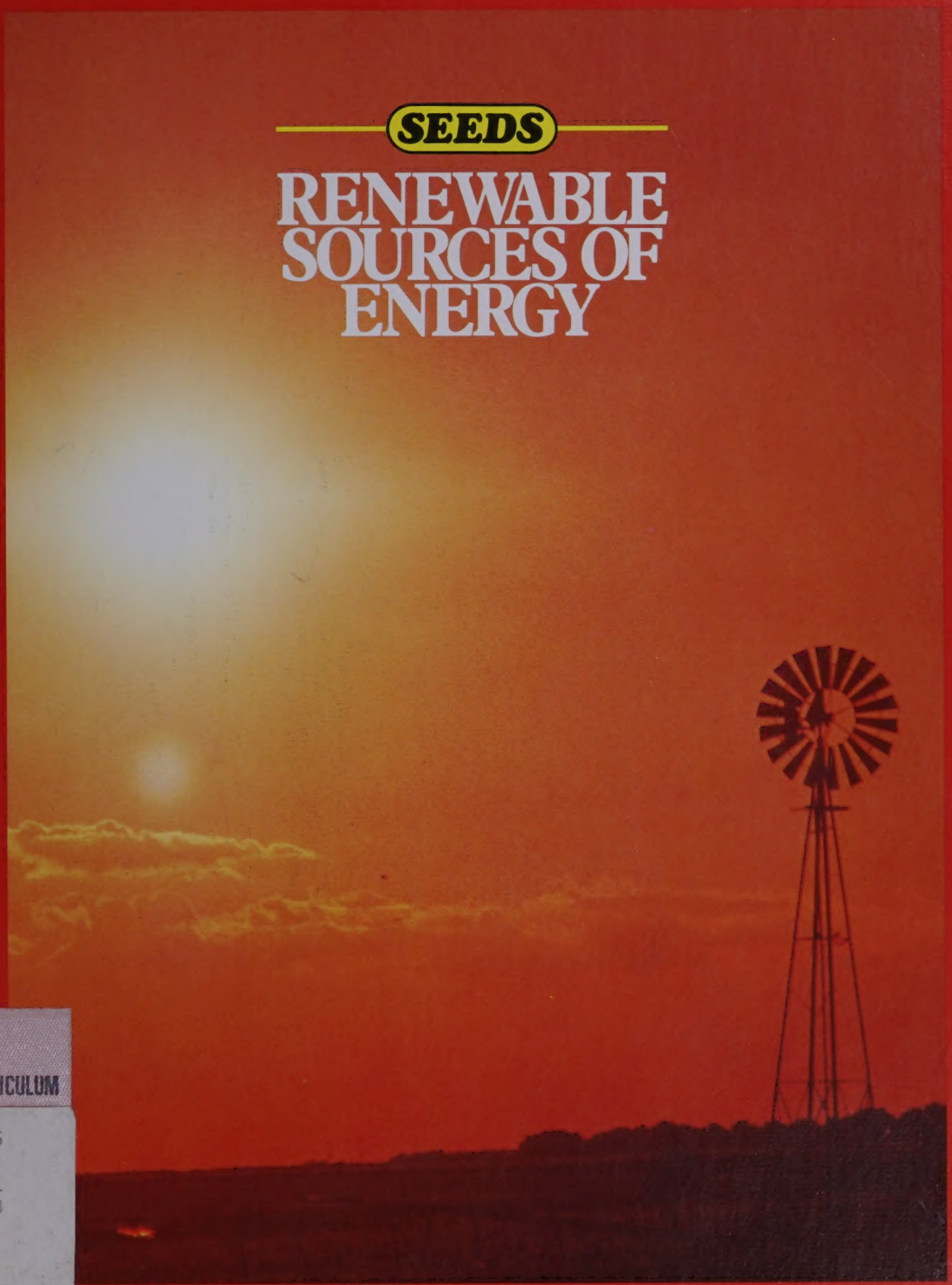
SEEDS

RENEWABLE SOURCES OF ENERGY



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The Energy Literacy Series

RENEWABLE SOURCES OF ENERGY

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1

Renewable Sources of Energy

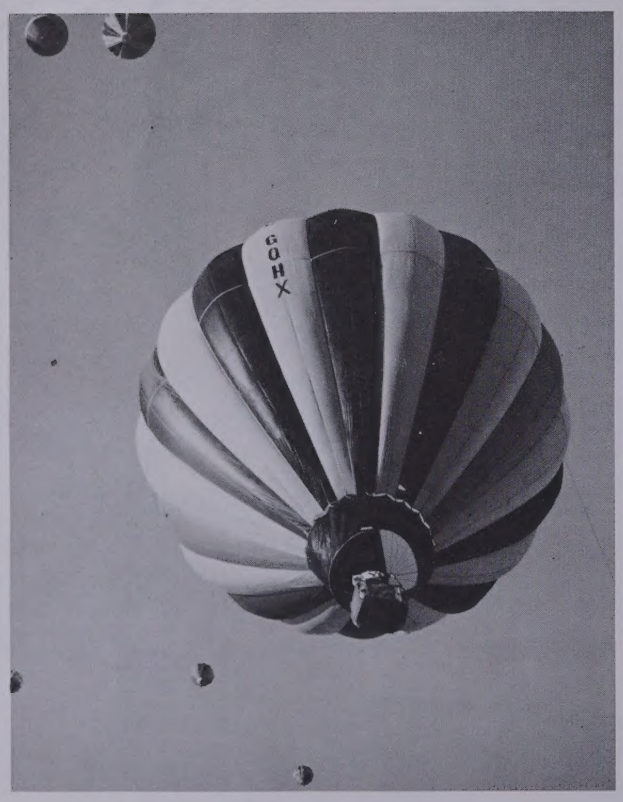
What Is Energy?

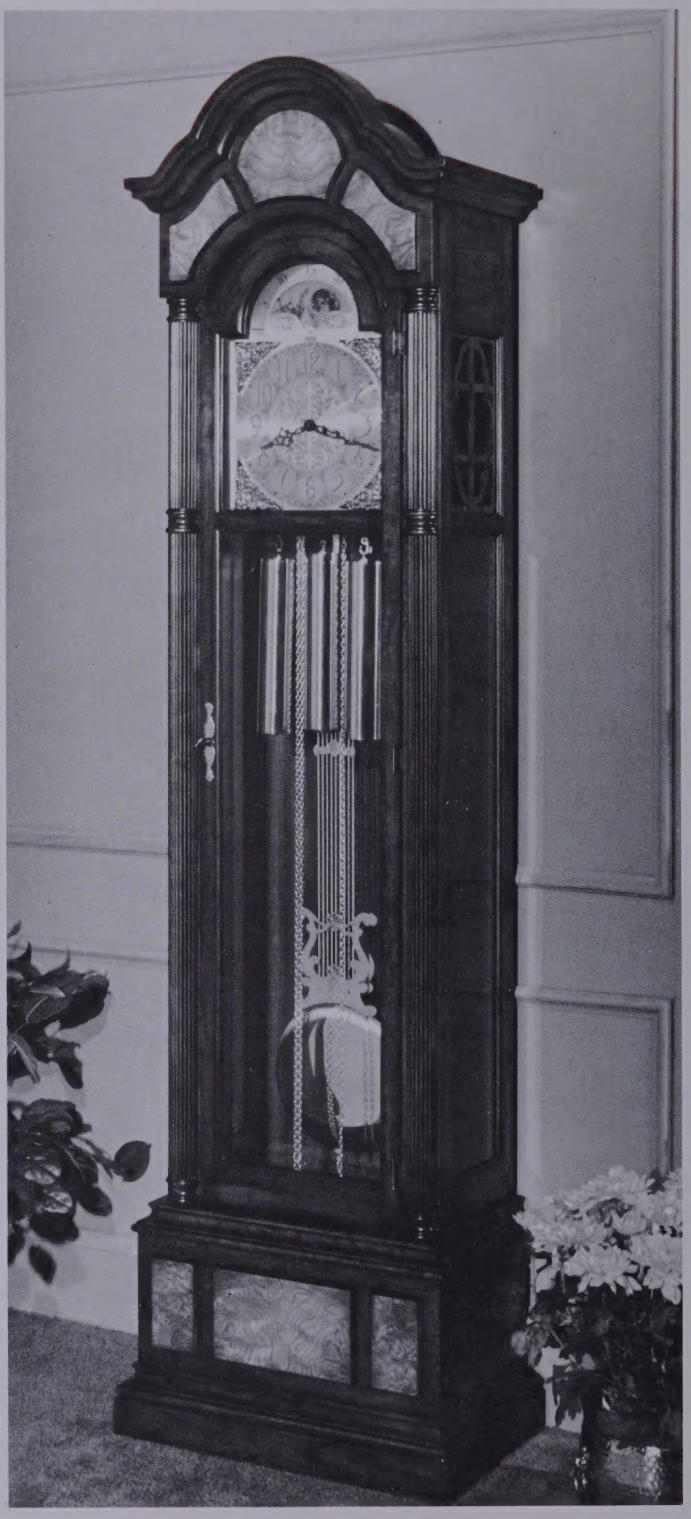
What do we mean when we speak of energy? Energy can be defined as the ability to start something moving (like a ball or an automobile), to change its motion (such as stopping a basketball, or changing the speed of a skipping rope), to heat up an object (a pizza, or a soldering iron), or to change the shape of something (such as compressing a spring). There are many different forms of energy. There is mechanical, electrical, chemical, and heat energy. In this sense there is no shortage of energy. For instance, there is energy all around us in the form of heat contained in every object caused by the random motion of its molecules.

The problem is to harness one of these sources of energy to work for you.

The development of life as we know it in North America can be traced through the story of humankind's discovery and use of new energy resources. The discovery of fire, the domestication of animals, the development of windmills and watermills, the invention of the steam engine, and the use of coal and oil are some of the important milestones in this history. Each discovery increased our control over our environment and led to revolutionary changes in society.

What Form of Energy?





What Are Renewable Sources of Energy?

In the beginning, the only known source of energy was human muscle. Hard physical labor was later supplemented by trained animals, which was followed by wood, water, and wind power. The burning of wood created heat power, and the force of swift streams and strong winds was used in watermills and windmills to operate machinery that would have taken several hundred workers to move. The steam engine was invented in the nineteenth century. It could do four times the amount of work of the watermills. At first the steam engine burned wood to make it go. In quick succession wood was replaced by coal, followed in its turn by oil and natural gas.

Years ago, people believed that new suppliers of oil, coal, and natural gas would supply energy needs forever. Now we know this is not so. What advances will be made in the future? Will our energy continue to come from oil and natural gas? Will it be supplied by nuclear reactors? Or will people return to the use of renewable resources? Such sources include sunlight, wind, tides, ocean temperature differences, and biomass gases from waste vegetation. These are sources that will not run out. They will last as long as the sun shines and the earth continues to turn on its axis.

Critics of renewable energy resources state that these energy sources will have little effect before the year 2000. Yet in many cases the technology needed to use these sources is already available. As the nonrenewable sources begin to be depleted and energy costs skyrocket, people perhaps will be willing to invest their time and money in the task of speeding up the development of renewable energy resources. Of course, many people are already using renewable forms of energy in many different ways. There are many machines on the market that use the sun for their energy source.

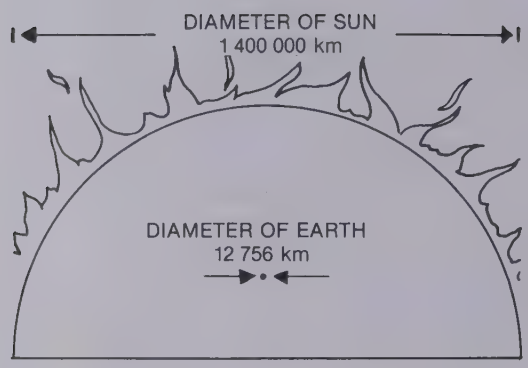
People in some countries have never stopped using wind as energy to pump water. And many people have never stopped using trees as a source of energy.

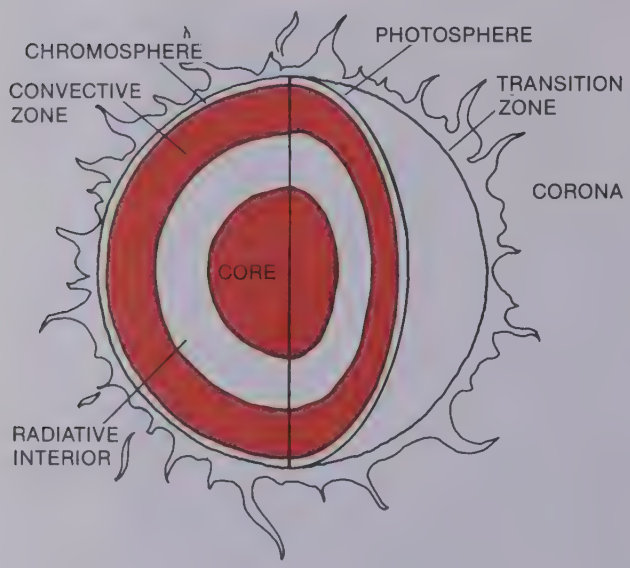
Are renewables the answer to the energy crisis? Perhaps when you have finished this unit of study, you will have a better idea of the usefulness of renewable energy sources, today and tomorrow.

What Source of Energy?

EMPIRE
NOSEGA
TOBACCO

2
Solar Energy





What Is Solar Energy?

Humans have always been curious about the sun. Early peoples recognized the sun as the source of light and heat. At various times, the sun has been:

- worshipped as a god,
- thought of as a burning pile of wood, and
- viewed as a large ball of burning gas.

The view of the sun as a large ball of burning gas was popular in the 18th century. In the 19th century, many scientists believed the burning gas to be hydrogen. Since then, discoveries about the atom have helped us to understand more about the sun.

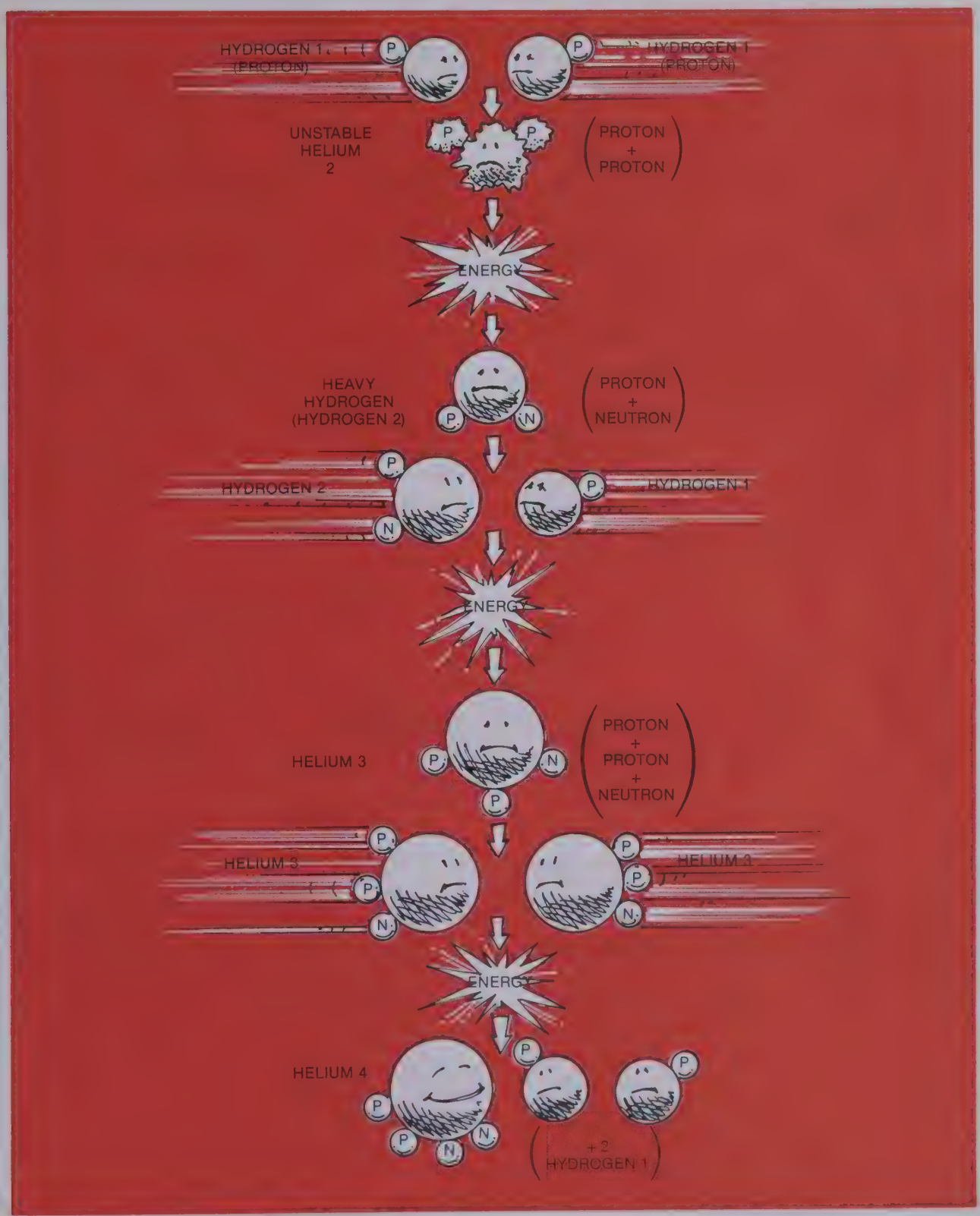
The sun is truly a large ball. It is a sphere with a diameter of one million four hundred thousand kilometers.

The diameter of the sun is over one hundred times the diameter of the earth. The volume of the sun is over a million times the volume of the earth.

We now think that the sun is more than a ball of gas. In the sun, the pressure is so great and the atoms are packed so closely that the matter in the core has about eight times the density of lead.

The temperature at the core may be as high as 20 000 000°C. At such high pressure and temperature, matter does not exist as solid, liquid, or gas, but in a fourth state called plasma. In this state, the nuclei of the atoms have been stripped of their electrons.

We also think that the sun is doing more than burning. In the plasma in the core of the sun, the proton-proton reaction fuses hydrogen into helium. When this happens, energy is given off.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HYDROGEN 1
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UNSTABLE
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2
PROTON
+
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ENERGY
HEAVY
HYDROGEN
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+
NEUTRON
HYDROGEN 2
HYDROGEN 1
ENERGY
HELIUM 3
PROTON
+
PROTON
+
NEUTRON
HELIUM 3
HELIUM 3
ENERGY
HELIUM 4
+ 2
HYDROGEN 1

How Much Energy Does the Sun Supply?

Scientists estimate that, in the sun, four million tonnes of hydrogen are changed to solar energy each second. One half of one billionth of this energy reaches the earth. That may not seem to be a lot of energy. Still, every second, eighty billion megajoules of energy reach the earth from the sun. In order to get a feeling for how much this is, consider the following:

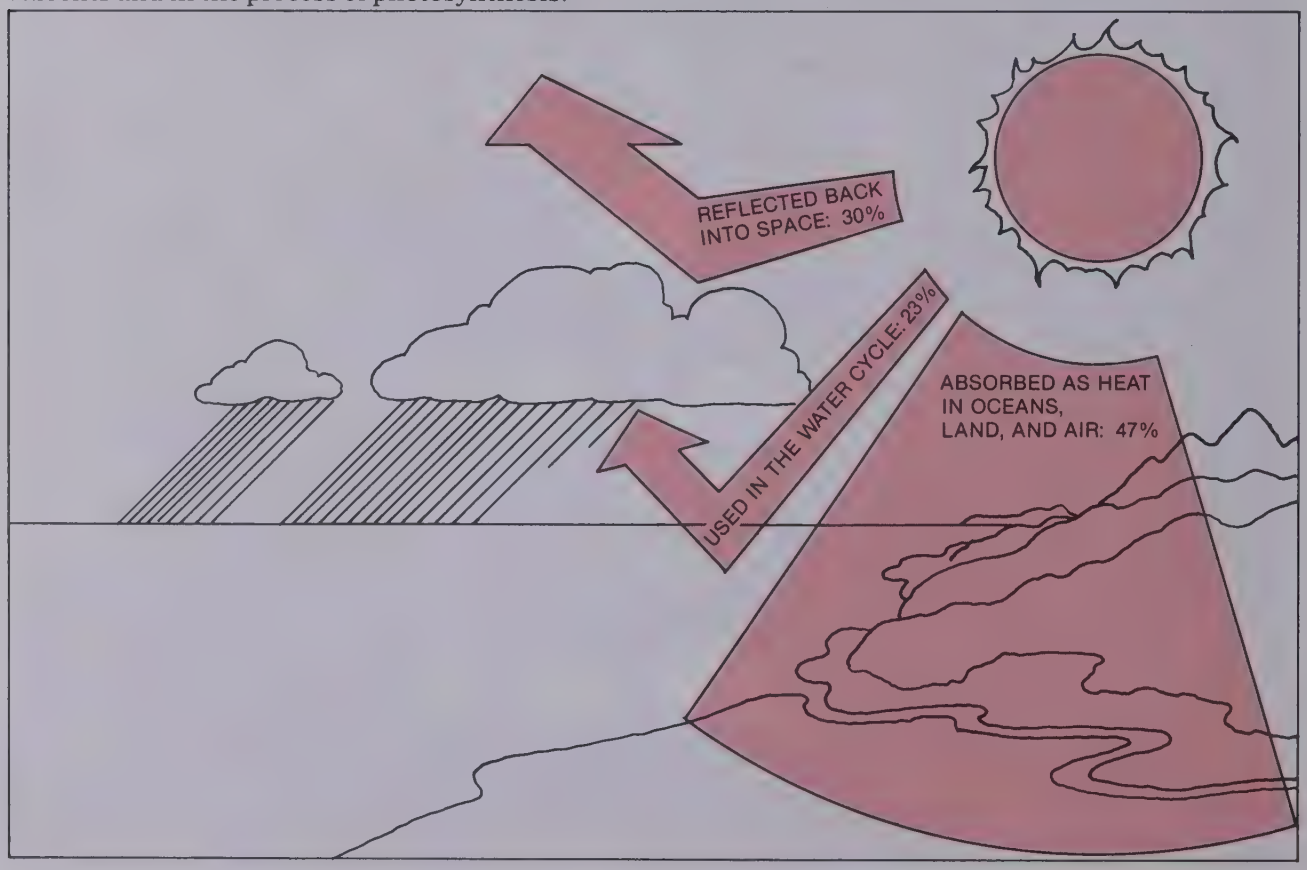
- 1 J (one joule) is the amount of energy required for you to lift a flashlight battery in your hand one metre.
- 1 mJ (one megajoule) is a million joules. The picture below illustrates what happens to the solar energy that reaches the earth.

The table to the right shows the amount of solar energy that reaches the ground in Edmonton, Alberta during one year on an area the size of two quarters.

The diagram below shows that a very small amount of the energy the earth receives from the sun (less than 1%) is used in wind and ocean currents and in the process of photosynthesis.

MONTH	JOULES	MONTH	JOULES
January	91 200	July	569 000
February	153 600	August	445 600
March	312 000	September	308 800
April	420 800	October	203 200
May	510 400	November	98 400
June	532 000	December	68 000
TOTAL 3 713 600 J			

The yearly total is about the same amount of energy used by ten 100-W lightbulbs burning for one hour. This equals one kilowatt hour.



What Are the Uses of Solar Energy?

If we were able to collect all the solar energy that strikes the earth in a fifteen-minute period we would have an amount equal to all the electrical energy used throughout the world for a full year. In a three-month period, the amount of solar energy that strikes the earth is equal to the energy contained in the total world reserves of non-recurring energy.

Much research is needed to solve two problems:

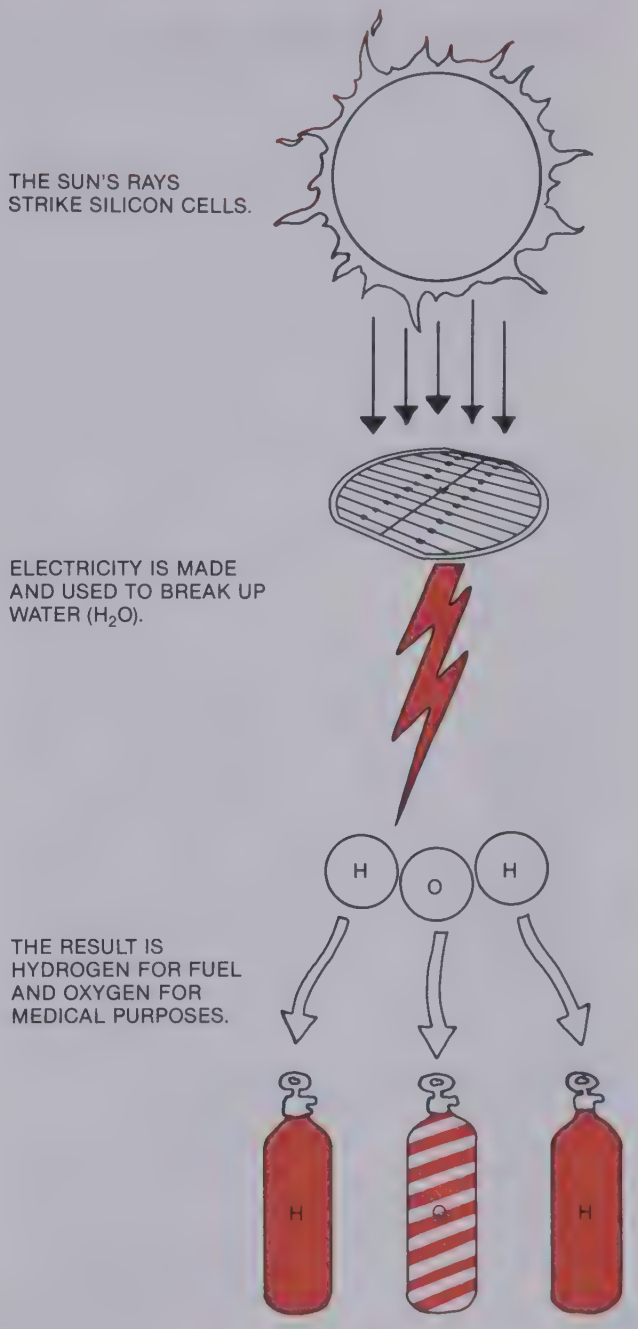
- developing technology to collect and store solar energy, and
- lowering the cost of the technology.

Sunlight can be changed into electricity by using silicon cells. Satellites use this method now but at a high cost. The cost of the silicon cells needed to produce one kilowatt of electricity is $50 000. With more research and mass production, we may be able to bring the cost of a one-kilowatt cell down to $500. Research is also needed to make solar collectors smaller. The silicon cells required to produce enough electricity for a typical Canadian city would cover an area the size of the city itself.

One problem with solar energy is storing it for times when the sun's energy is not reaching the earth. Scientists are now working on a method to use solar energy to create hydrogen.

Hydrogen could be used to power cars, trucks, thermal-electrical generators or any other motor-driven machine. Scientists in California have recently discovered that rhodium, when struck by the sun's rays, acts as a catalyst in the production of hydrogen.

Using solar energy to produce electricity and hydrogen fuel will become very important in the future. Today, the most practical use of solar energy is in heating homes. The cost of a solar collector is very reasonable. In the near future, many people should be able to afford to buy or build one.



3

Demonstrating Solar Energy

How Can the Sun's Energy Be Captured?

In the activity that follows, you are asked to experiment. Experiments are very important to scientists. People may set up experiments for one of two reasons.

- To test a new idea. The idea is called the hypothesis, or purpose, of the experiment. In the experiment that follows, the idea is that angle of the energy source has something to do with the amount of energy a collector can capture. The hypothesis must be written accurately. The hypothesis is that the angle of the burning lightbulb affects the speed at which the vanes of the radiometer revolve.
- To test the conclusion of an experiment done by someone else. The experiment that follows has been done by many scientists and students. Those who first did the experiment thought they had discovered something about the hypothesis—whether or not it is true or false. (If the hypothesis is found to be true, it is confirmed; if it is found to be false, it is rejected.) When you have finished the experiment that follows, you should be able to confirm or reject the hypothesis.

Before you start to do the experiment, read the *Steps of an Experiment* at the top of the next column. Make sure you understand each step before you begin the experiment.

Steps of an Experiment

HYPOTHESIS The hypothesis is explained in the column to the left. Review the explanation to make sure you understand what the hypothesis is.

MATERIALS The materials are the pieces of equipment you will need to do the experiment. The experiment that follows uses a radiometer. A radiometer is a device that can help to demonstrate some of the energy present in light. Here the energy source is a lightbulb. The lightbulb is easier to experiment with than the sun for two reasons. First, you can move the lightbulb around, but you must wait for the earth to revolve for the angle of the sun to change. Second, the angle of the lightbulb is easier to check than the angle of the sun. The materials you use must be practical.

PROCEDURE The procedure is what you do with the materials. Always follow the procedure carefully and record exactly what you have done.

OBSERVATION Observations are statements about what happens to the materials during the procedure. After writing what you have done, write what you observe.

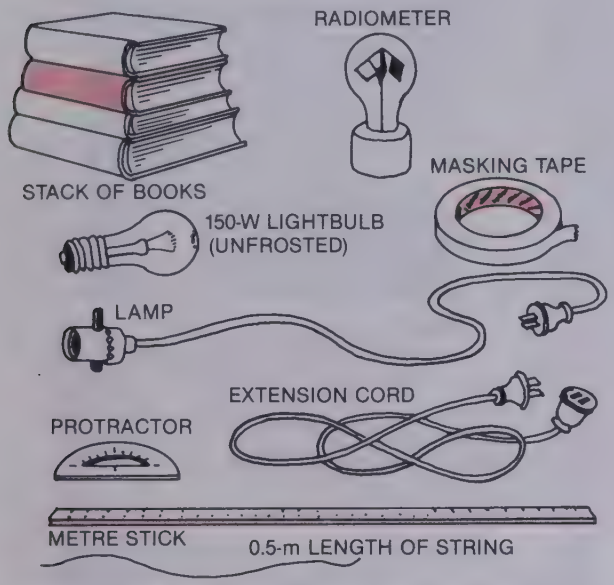
CONCLUSION At the end of the experiment, write your conclusion. In your conclusion you should confirm or reject the hypothesis and give your reasons.

Activity

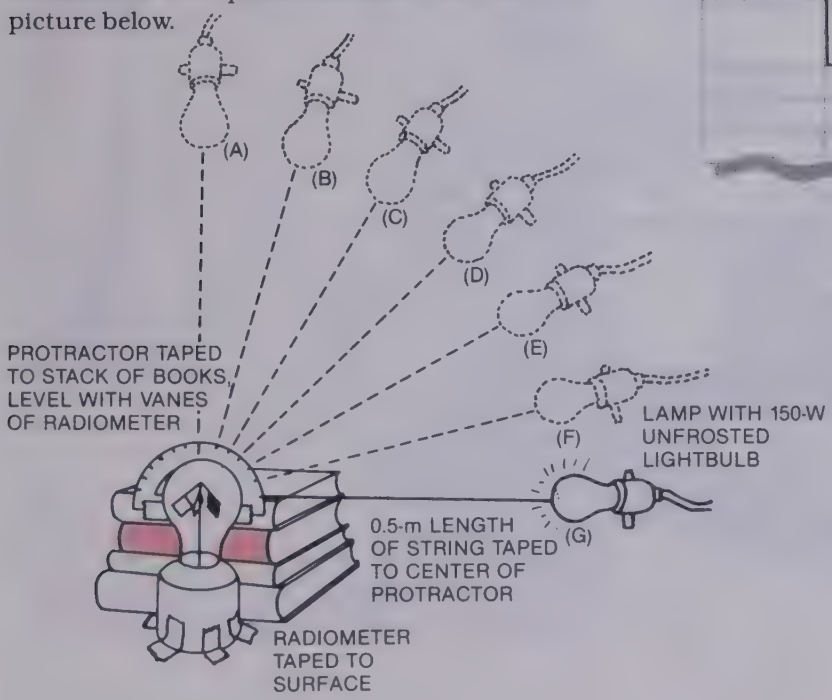
Experiment 1: An Experiment with Light

HYPOTHESIS The angle of a burning lightbulb affects the speed at which the vanes of a radiometer revolve.

MATERIALS You will need a radiometer, a lamp, an extension cord, a 150–W lightbulb, a protractor, a metre stick, a 0.5-m length of string, masking tape, and two stacks of books.



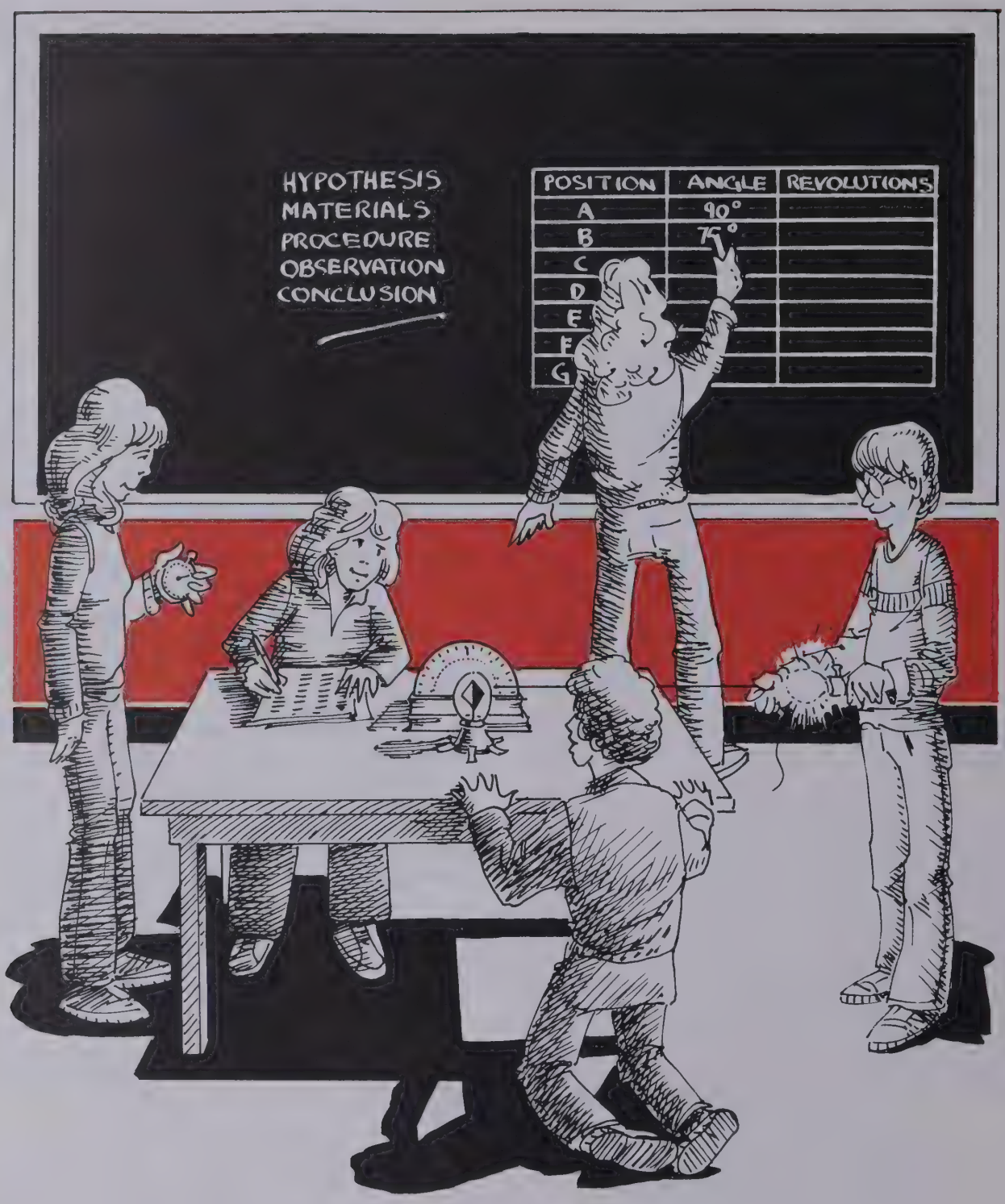
PROCEDURE Set up the materials as shown in the picture below.



See page 16 for a picture of how to work in teams. One person reads the angle of the string on the protractor. Another person plugs in the lamp and holds the lightbulb at position (a) (90°) for one minute. Another person watches the clock or the stopwatch for the beginning and end of one minute. Let the vanes of the radiometer stop at the end of each reading.

OBSERVATION Another person, the observer, watches one vane of the radiometer to see how many times it revolves in one minute. As the lightbulb is moved to each new position, another person, the recorder, writes down the observations on a chart like the one below.

POSITION	ANGLE	REVOLUTIONS
(a)	90°	
(b)	75°	
(c)	60°	
(d)	45°	
(e)	30°	
(f)	15°	
(g)	0°	


HYPOTHESIS
MATERIALS
PROCEDURE
OBSERVATION
CONCLUSION
POSITION
ANGLE
REVOLUTIONS
A
90°
B
75°
C
D
E
F
G

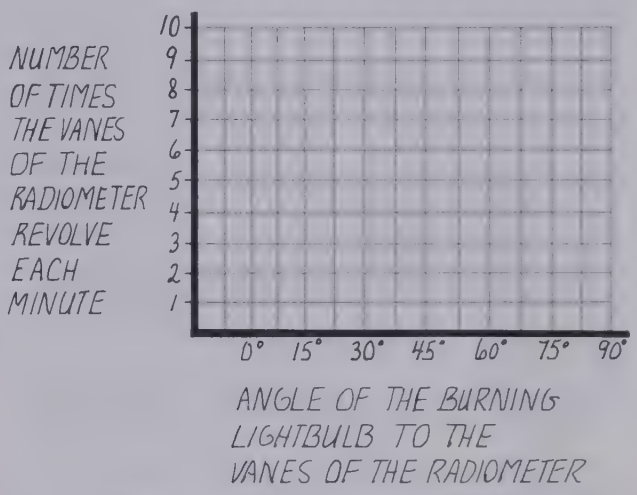
CONCLUSION When you have finished the experiment, you should study your observations and write a conclusion. Remember that, in your conclusion, you are to confirm or reject the hypothesis. Look at your observation chart. If the vanes of the radiometer revolve at the same speed no matter what the angle of the lightbulb, you should reject the hypothesis. Your conclusion would be that the angle of a burning lightbulb does *not* affect the speed at which the vanes of a radiometer revolve. If the vanes of the radiometer revolve at different speeds for different angles of the lightbulb, you should confirm the hypothesis. In that case, your conclusion would be that the angle of a burning lightbulb *does* affect the speed at which the vanes of a radiometer revolve.

After you have written your conclusion, you should state why the observations you have made support your conclusion. This is a very important part of doing an experiment. Your observations may support your conclusion, but your reason for thinking so may be wrong.

Review of Experiment 1

Before you go on to the next page, do the following:

1. What is the purpose of any experiment?
2. What are the steps of an experiment?
3. Write up the radiometer experiment according to the steps you listed in number 2.
4. At the bottom of page 15, there is a sample chart for recording observations. You should have a similar chart in your answer to number 3. If not, go back and make one now. Use the observation chart to make a bar graph. You might like to set up your graph like the picture below. Call your graph *Observations of the Experiment*.



5. Compare your observation chart with your bar graph.
   a. Which has more precise data? If you do not know the meaning of the word *precise*, look it up in a dictionary.
   b. Which is easier to read?

Activity

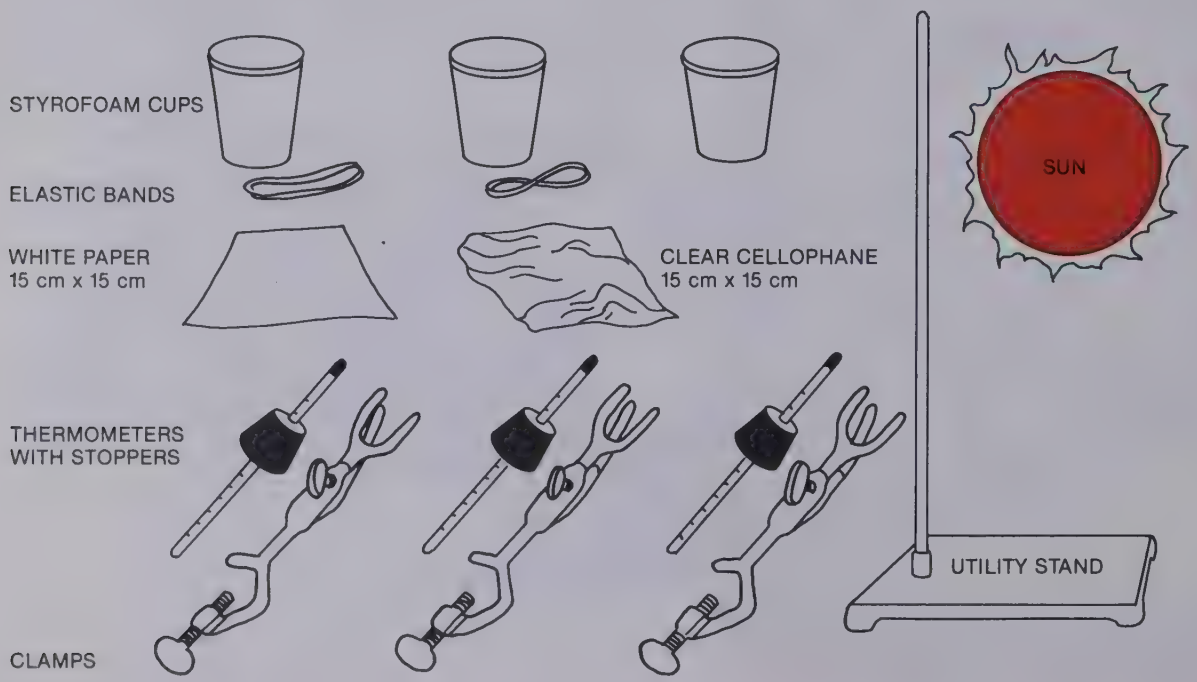
Experiment 2: Do Different Materials Retain Heat in Different Ways?

HYPOTHESIS When the inside of a Styrofoam cup is heated by the rays of the sun, the type of cover on the cup affects the change of temperature.

MATERIALS You will need three Styrofoam cups, a 15 cm × 15 cm piece of clear cellophane (or clear plastic wrap), a 15 cm × 15 cm piece of white paper, two elastic bands, three thermometers inserted in stoppers, three utility clamps, a utility stand, and a source of energy (the sun).

In experiments, materials are very important. Take time to consider why you should be using these materials.

- Styrofoam cups. The experiment has to do with temperature. Styrofoam does not conduct heat easily. That is why it is often used for coffee cups.
- Clear cellophane, white paper. The hypothesis talks about whether different types of covers affect the temperature inside a cup. Here we have cellophane, which is clear, and white paper, which is translucent. Look up the word *translucent* in a dictionary to make sure you know what it means. (In this experiment, you will be checking the temperature in *three* cups. Why are there not three types of covers? Sometimes the lack of a material tells something about the experiment.)
- Elastic bands. These are to hold the covers on.
- Thermometers and stoppers. The thermometers measure the temperature inside the cups. You will be putting the thermometers through stoppers. Then you will put the stoppers through holes in the bottoms of the cups. The stoppers plug the holes in the cups and also provide something large for the clamps to hold onto.
- Clamps. These attach the stoppers to the stand and help adjust the angle of the cups to the sun. (In Experiment 1, you learned something about the angle of the source of energy. This might be a good time to look again at the conclusions you wrote for that experiment.) In this experiment, you are finding out about covers. You want all three cups to be at the same angle to the sun. Can you think why?
- Stand. This holds all three cups in roughly the same place.

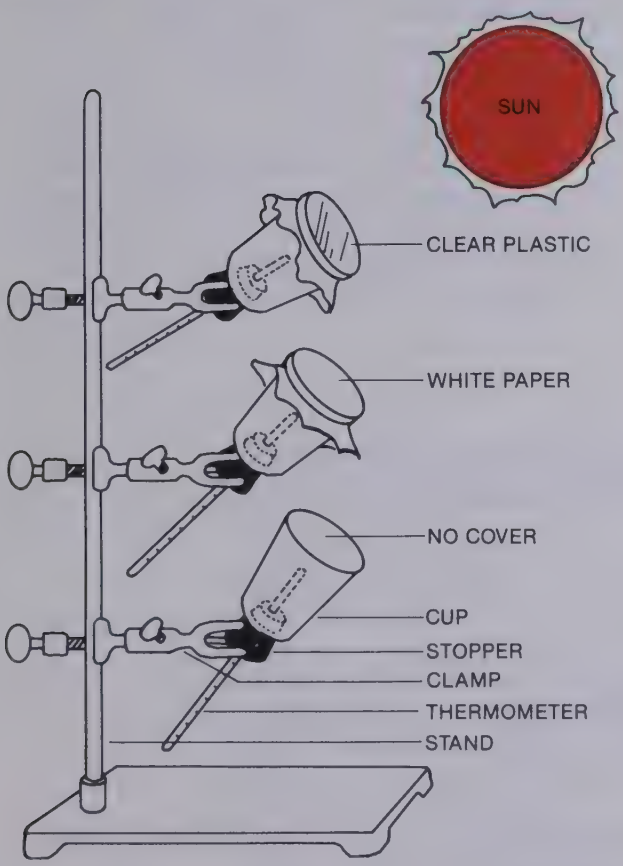


PROCEDURE Put each thermometer through a stopper. *Be very careful*. Thermometers are expensive; they break easily, and they can cut you very badly. In any experiment, handle all materials carefully.

Make a hole in the bottom of each cup and plug the hole with the stopper. The bottom of the thermometer should now be inside the cup. (You can tell the bottom of the thermometer from the top by the fact that the bottom has lower numbers than the top.)

Using elastic bands, cover the open end of one cup with cellophane. Cover the open end of another cup with white paper. Do not cover the third cup.

Use the clamps to attach all three cups to the stand.



Tilt each cup so that the sun's rays enter, leaving no shadow on the bottom. *Do not look directly at the sun. Do not look directly at reflections of the sun's rays from the cellophane or Styrofoam.* Doing so can cause permanent eye damage.

OBSERVATION Read the temperature from each thermometer and record each reading. After ten minutes you will read the temperature for each thermometer again. You might like to use the ten-minute wait to make a chart like this one, filling in each Starting Temperature.

OBSERVATION CHART

TYPE OF COVER	STARTING TEMP. (°C)	FINAL TEMP. (°C)	CHANGE IN TEMP. (°C)
OPEN			
CLEAR CELLOPHANE			
WHITE PAPER			

Ten minutes after you first read the temperature, read the temperature from each thermometer again. Fill in the final temperature on your chart. Subtract each Starting Temperature from each Final Temperature and write the result in the column *Change in Temperature*.

CONCLUSION Remember that in your conclusion you are to confirm or reject the hypothesis. If you confirm the hypothesis, your conclusion will be that when the inside of a Styrofoam cup is heated by the rays of the sun, the type of cover affects the change in temperature. If you reject the hypothesis, your conclusion will be that when a Styrofoam cup is heated by the rays of the sun, the type of cover *does not* affect the change in temperature. After stating your conclusion, give your reasons.

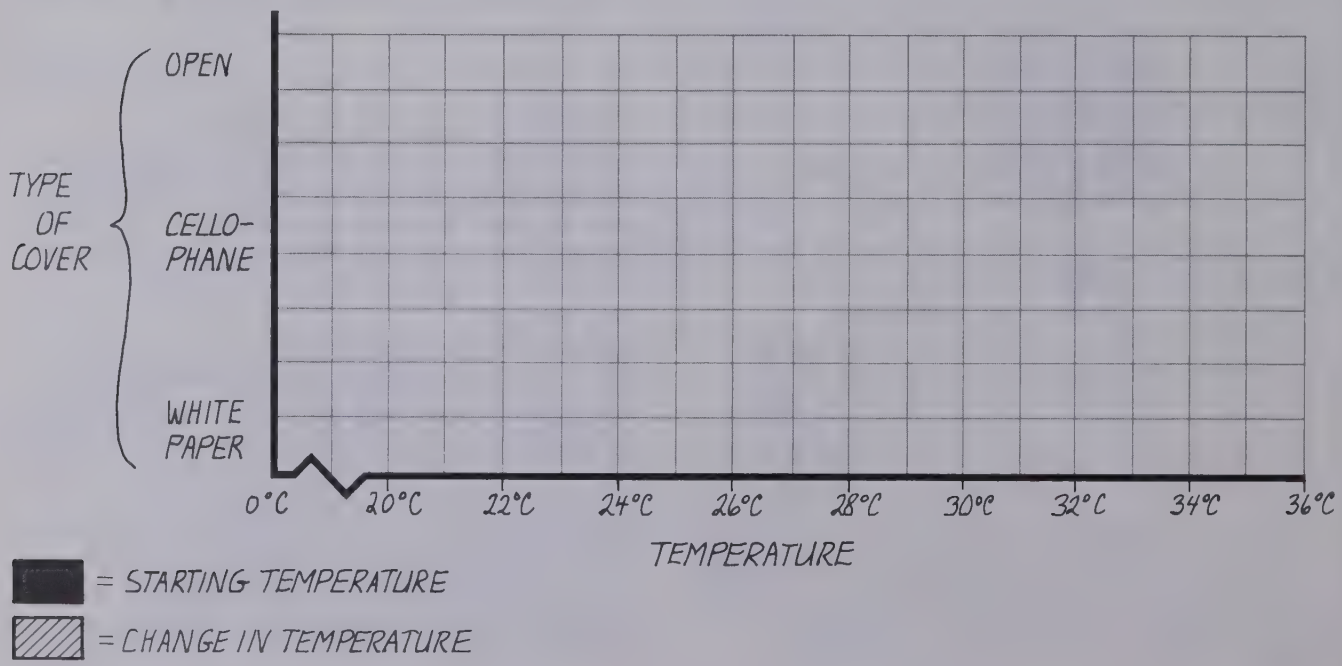
Review of Experiment 2

Before you go on to the next experiment, do the following:

1. List the steps of any experiment.
2. In this experiment the materials are especially important.
   a. Why is it important that the cups be made of Styrofoam?
   b. Why are elastic bands better than string for this experiment?
   c. What are the clamps used for?
   d. Give two uses for the stoppers.
   e. Why are thermometers used in this experiment and not in Experiment 1?
   f. Why is it better to clamp the cups onto a stand than to simply place the cups on a table? Give two reasons.
   g. This experiment uses the rays of the sun. You may have used a 150-W lightbulb instead. If you did use a 150-W lightbulb, state why. If you used the rays of the sun, state why you think someone might decide to use a lightbulb instead.
   h. Why is one cup covered with white paper?
   i. Why is one cup covered with clear cellophane?
   j. Why does one cup have no cover at all?
   k. Many experiments have materials that can be dangerous if not handled carefully. Which materials in this experiment are dangerous? Why? (You might start a section in your notebook called *Dangerous Materials*.)
3. Write up Experiment 2 according to the steps you listed for question 1.
4. In your answer to question 3 you should have a section called *Observation*. In this section you should have a chart like the one in the second column of page 19. If you do not have this chart in your Observation section, go back and put it in now.

   Use the Observation Chart to make a Bar Graph like the one below.

   First make a solid bar for each starting temperature. Next find each final temperature. Then extend each bar to the final temperature using diagonal lines or by using different colors.
   a. Double check your Bar Graph. Are your starting temperatures and final temperatures the same as those on your Observation Chart?
   b. Compare your Observation Chart with your Bar Graph. Which has more precise data?
   c. Is it easier to read the change in temperature on the Observation Chart or on the Bar Graph? Which shows the conclusion of the experiment better?

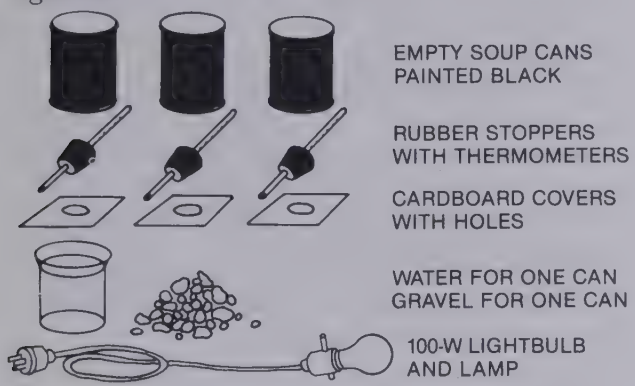


Activity

Experiment 3: Do Different Materials Absorb Heat in Different Ways?

HYPOTHESIS When a container is heated by a lightbulb placed outside it, the material inside the container affects the change of temperature.

MATERIALS You will need three empty soup cans painted black, three thermometers inserted in rubber stoppers, three cardboard covers with holes for the rubber stoppers, water at room temperature, gravel, a lamp and a 100-W lightbulb.

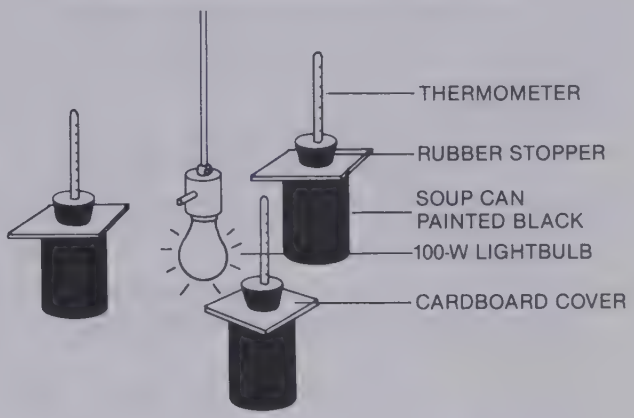

EMPTY SOUP CANS PAINTED BLACK
RUBBER STOPPERS WITH THERMOMETERS
CARDBOARD COVERS WITH HOLES
WATER FOR ONE CAN
GRAVEL FOR ONE CAN
100-W LIGHTBULB AND LAMP

In addition to the materials above, you will need to make a chart like the one below to record your observations.

PROCEDURE Almost fill one can with water at room temperature, and a second can with gravel. Leave the third can empty.

Insert a thermometer, bottom first, through a rubber stopper, through the hole in a cardboard cover, and into the water. Insert a second thermometer, bottom first, through a rubber stopper, through the hole in a cardboard cover, and into the gravel. *Be very careful working the thermometer into the gravel.* Insert a third thermometer, bottom first, through a rubber stopper, through the hole in a cardboard cover, and into the can containing the air.

Place each can 5 cm from the lightbulb.



OBSERVATION CHART

TIME	TEMPERATURE: °C			TIME	TEMPERATURE: °C			TIME	TEMPERATURE: °C		
MINUTES	AIR	WATER	GRAVEL	MINUTES	AIR	WATER	GRAVEL	MINUTES	AIR	WATER	GRAVEL
0				12				24			
1				13				25			
2				14				26			
3				15				27			
4				16				28			
5				17				29			
6				18				30			
7				19				31			
8				20				32			
9				21				33			
10				22				34			
11				23				35			

REMEMBER TO TURN THE LAMP OFF AFTER 15 MIN

OBSERVATION Read the thermometer for each can. Record the temperature for each can on your Observation Chart beside time zero.

Turn on the lamp.

On your Observation Chart, record the temperature for each can every minute for fifteen minutes.

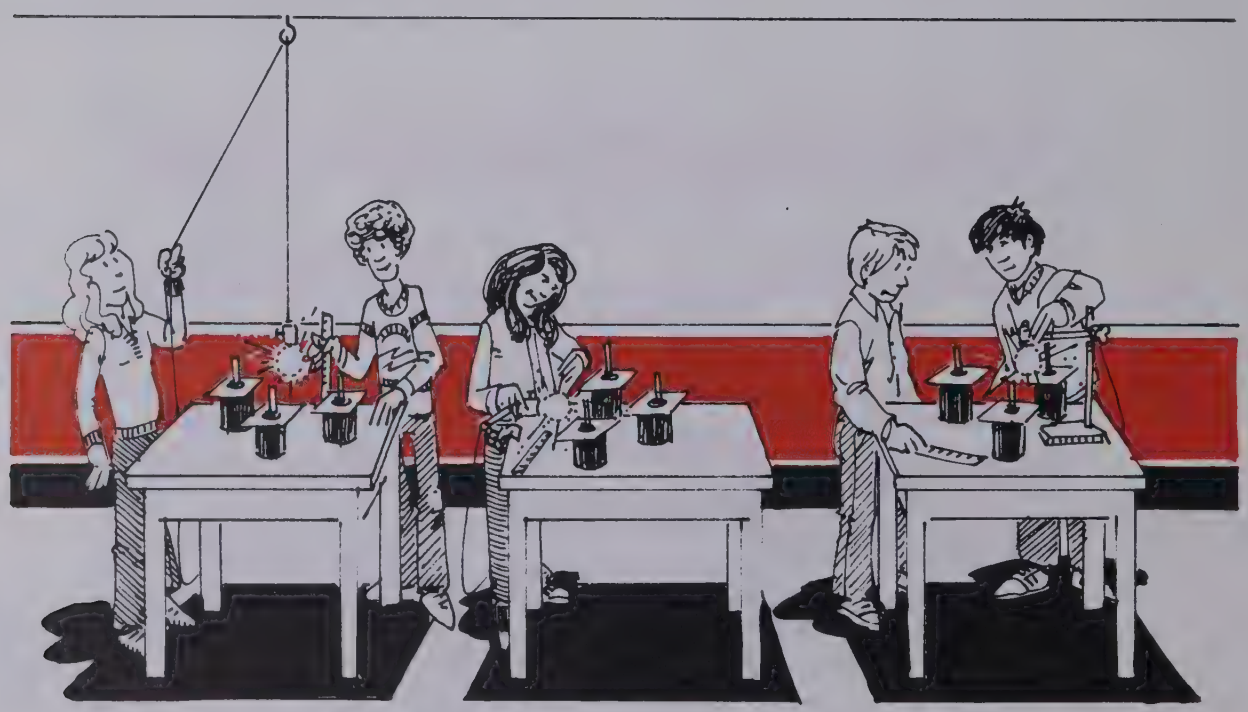
Turn off the lamp.

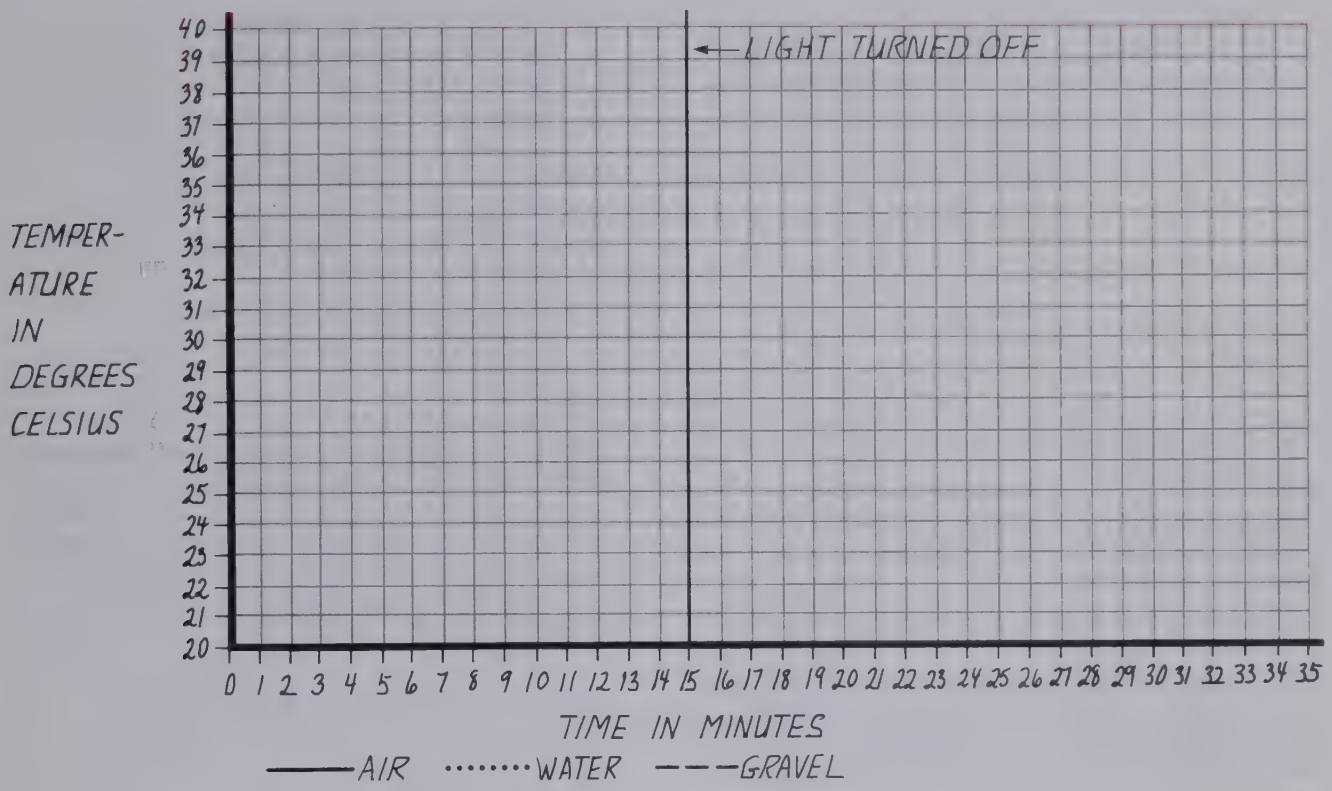
On your Observation Chart, record the temperature for each can every minute for twenty more minutes.

CONCLUSION The hypothesis is that, when a container is heated by a lightbulb placed outside it, the material inside the container affects the change in temperature. Do you confirm or reject the hypothesis? What are your reasons?

Review of Experiment 3

1. List the steps of any experiment.
2. Why is it important for all three soup cans to be the same size? What would happen if you used one very large can and two very small cans?
3. Why is it important for all three soup cans to be the same color? What would happen if you had used one white can and two black cans? Imagine that you are riding in a car on a hot summer day on your way to the beach. Imagine that the windows are rolled up. Which would be hotter, a white car or a black car? Why do tennis players and baseball players wear white? Why are the cans in the experiment painted black?
4. Why should the water used in the experiment be at room temperature?
5. Why should all three cans be the same distance from the lightbulb? What would happen if one can were farther away from the lightbulb than the other two cans?
6. How did you mount the lightbulb? Name two other ways you could have mounted it.
7. Look at your Observation Chart. Are all three starting temperatures about the same? If they are not, think of a possible explanation. How does your explanation relate to your answer for question 4, above?
8. Use the data on your Observation Chart to make a line graph. Set up your graph like the one at the top of page 23.





Put all of the temperatures for the can with air on the graph. Connect the points with a solid line. Next, put all the temperatures for the can with water on the graph. Connect these points with a dotted line. Finally, put all the temperatures for the can with gravel on the graph. Connect these points with a dashed line. Instead of using solid, dashed, and dotted lines, you could use three different colors.

9. If you have not already done so, write up Experiment 3 according to the steps you listed in number 1. Be sure to include both your Observation Chart and the graph you made of Observations of Experiment 3.

   Before you write your conclusion, look carefully at your graph. Think about the questions at the top of the column to the right. Do not write down answers to these questions. Instead, read them carefully and think about each one. Doing so will help you write a better conclusion.

   - About where do the temperatures start on your graph?
   - Which temperature rises fastest? Why?
   - Which temperature rises slowest? Why?
   - What happens after 15 min?
   - What did you do in the experiment that might account for what happens after 15 min?
   - What was the original hypothesis?
   - Will you confirm or reject the original hypothesis?
   - Does the experiment seem to show anything that the original hypothesis says nothing about?

10. Now write your conclusion. Remember that you are to confirm or reject the hypothesis. After you have done so, you should give your reasons. The reasons you give should be based on your observations.

    If you feel that the experiment shows more than what the hypothesis talks about, you may now write down what else you think you might have found out. Write a new hypothesis. Write a way to test your hypothesis using the Steps of an Experiment you have learned.

4
Using Solar Energy

The Greenhouse Effect

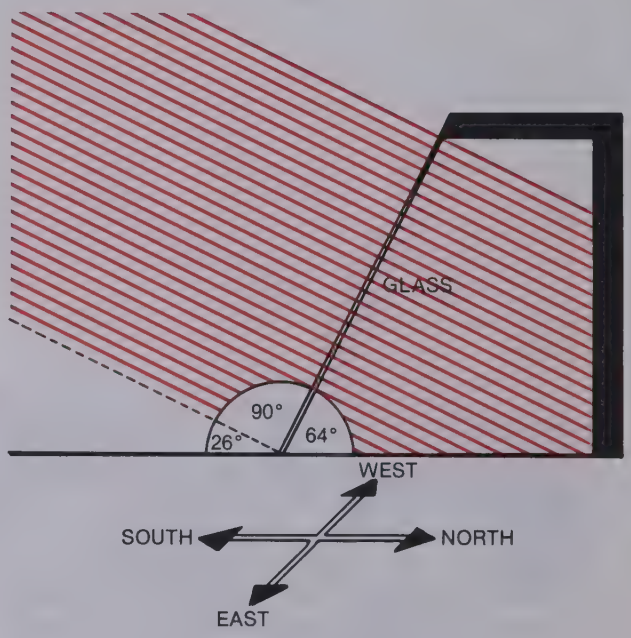
Experiments 1, 2, and 3 should have given you some insight into ways to capture the sun's energy. Remember that each experiment began with a hypothesis and ended with a conclusion. Each experiment was designed to test the hypothesis. Each conclusion was to be a statement on your part confirming or rejecting the hypothesis. In this section, you will read about ideas other people have had for capturing some of the sun's energy. As you are reading, ask yourself questions such as the following:

- How could I state this idea as a hypothesis?
- What kind of experiment would test this hypothesis?
- Would I like to test this hypothesis myself?

All greenhouses are at least partly heated by energy from the sun.

People who build greenhouses believe that they can best capture the sun's energy when the glass is at an angle of 90° to the rays of the sun. Look again at your write-up of Experiment 1 in Chapter 3. At what angle to the lightbulb did the vanes of the radiometer revolve the fastest?

SIDE-VIEW OF A TYPICAL GREENHOUSE LOCATED AROUND 47° NORTH LATITUDE



The sun is shown in its position in January and February, the coldest time of the year in the northern hemisphere.

The side view of the greenhouse on page 24 shows a greenhouse located at about 47° north latitude. St. John's, Newfoundland is roughly at this latitude. People who build greenhouses believe they can get the glass at a 90° angle to the rays of the sun if they add about 17° to the latitude of the greenhouse and locate the glass at that angle to the ground. St. John's is at about 47° north latitude.

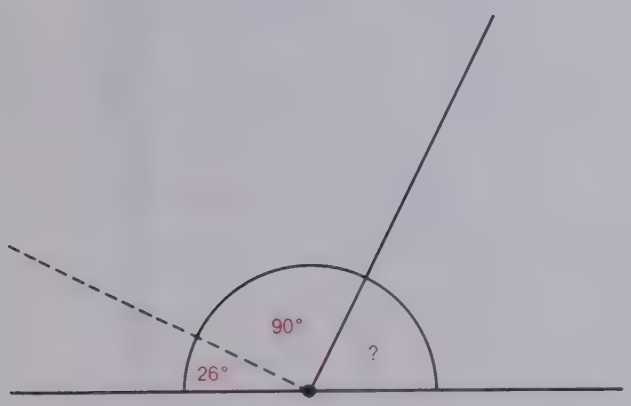
$47° + 17° = 64°$

latitude + 17° = angle of glass to the ground

According to this hypothesis, the glass in a greenhouse in St. John's should be at a 64° angle to the ground. Look at the greenhouse again. Is the glass at the proper angle?

There is another way to compute the angle of the glass to the ground. At the coldest time of the year, the sun's rays strike the ground at St. John's at an angle of about 26°. Use your protractor to make a drawing like the one below.

Now put the base line of your protractor along the dashed line with the center on the dot and make a 90° angle.



You now have two angles. Measure the third angle. How many degrees does it have?

There is a third way to compute the angle of the glass to the ground. Look at the drawing below.

The protractor measures the number of degrees in one half of a circle. If you look at your protractor you can see that the total number of degrees is 180. You have three angles to fit into half of a circle. You already know the number of degrees in two of the angles. Add them together.

$$\underbrace{26°}_{\text{angle of the sun's rays to the ground}} + \underbrace{90°}_{\text{angle of the glass to the sun's rays}} = 116°$$

Now subtract from 180°.

$$\underbrace{180°}_{\text{total degrees in one half of a circle}} - \underbrace{116°}_{\text{sum of the other two angles}} = \underbrace{64°}_{\text{angle of the glass to the ground}}$$

From doing Experiment 1, you have reached a conclusion about the effect of the angle of a source of energy to the vanes of a radiometer. Those who build greenhouses believe that the best angle of the glass to the rays of the sun is 90°. Do you agree?

Also, greenhouse builders have three ways of computing the angle of the glass to the ground. Make sure you understand all three ways to do this.

When the sun's rays enter a greenhouse, they go directly through the glass and strike the walls and the floor.

Some of the sun's rays are absorbed by the walls and some are reflected back. The walls radiate back the heat they have absorbed from the sun's rays.

Some of the sun's rays are absorbed by the floor and some are reflected back. The floor also radiates the heat from the sun's rays.

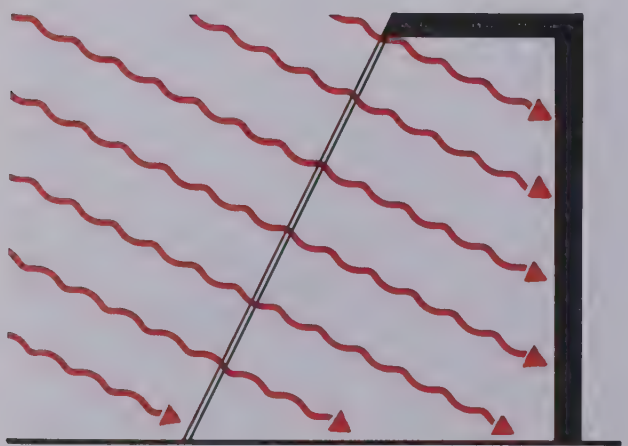
Do you know what the word *reflected* means? Do you know what the word *radiated* means? If you do not, look up the words in a dictionary. What does a reflector do? What does a radiator do? Some of the energy that is radiated back is in the form of infrared light. Of all visible light, red light has the least energy. Infrared light is invisible light whose energy is even less than that of red light. Look at the word *infrared*.

infrared

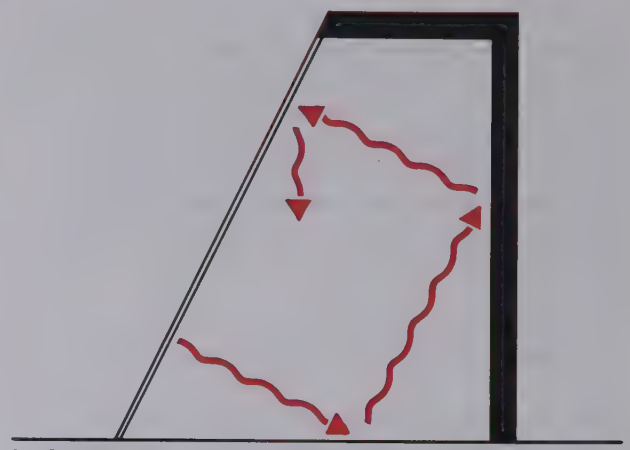
infra- This means *lower than.*

red This means *red light in energy.*

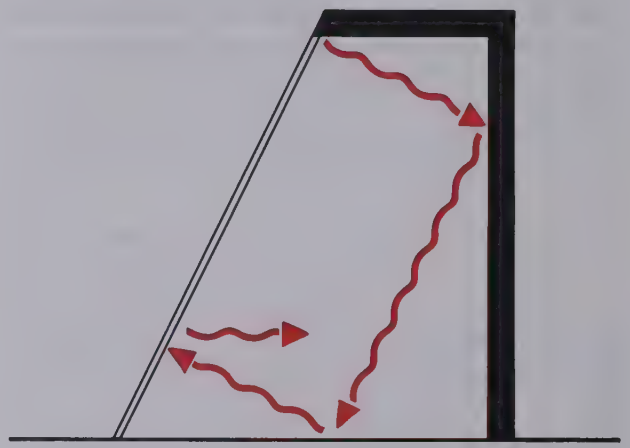
Glass is opaque to infrared light. This means that infrared light rays will not go back out through the glass. Instead, they bounce around and warm the air in the greenhouse. This is called the Greenhouse Effect.



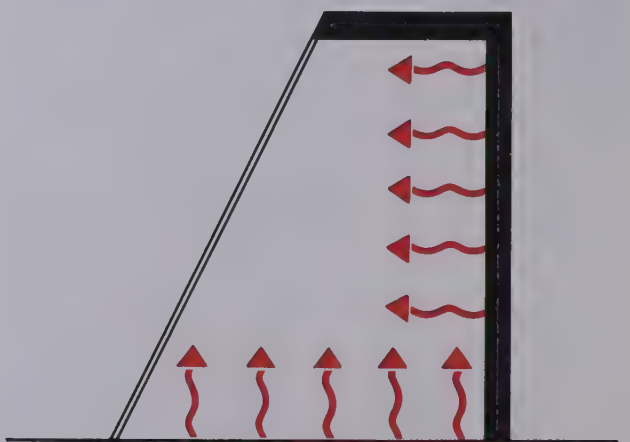
1. SUN'S RAYS STRIKE WALLS AND FLOOR.



2. SUN'S RAYS PARTLY ABSORBED BY WALLS AND PARTLY REFLECTED BACK.



3. SUN'S RAYS PARTLY ABSORBED BY FLOOR AND PARTLY REFLECTED BACK.



4. WALLS AND FLOOR BOTH RADIATE HEAT.

Look again at your write-up of Experiment 2. Which cover created the best rise in temperature: the opaque cover, the clear cover, or no cover at all? Now that you have learned about the Greenhouse Effect, how would you explain your results in Experiment 2?

Remember that some of the sun's rays are absorbed by the walls and the floor. When evening comes, and the sun's rays are no longer coming in, the walls and floor begin to cool. As they do so, they release heat into the air of the greenhouse, helping to warm it at night.

Many homes make use of the Greenhouse Effect. Homes with large windows facing south can capture enough of the sun's energy to lower their heating costs in the winter.

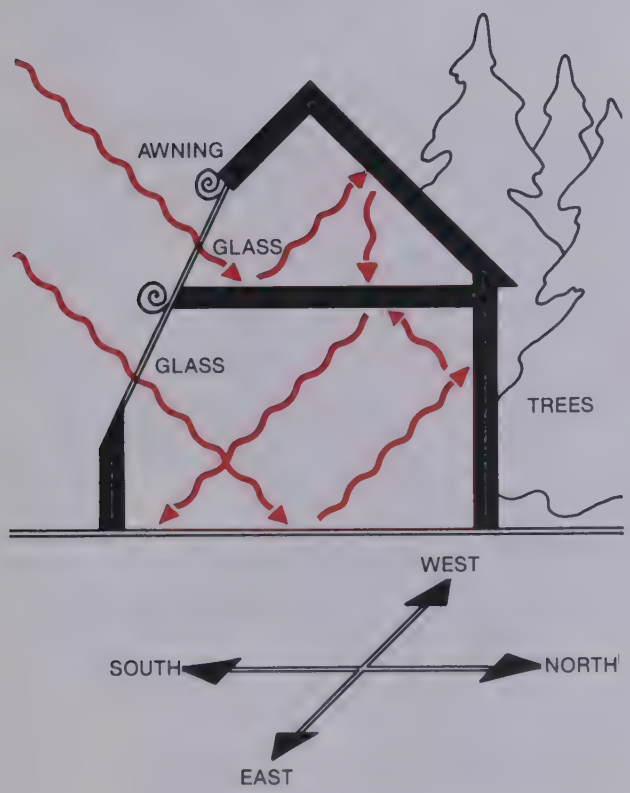
Some people do not like having to tilt their windows so much. A window in the roof can allow the sun's rays to strike a back wall.

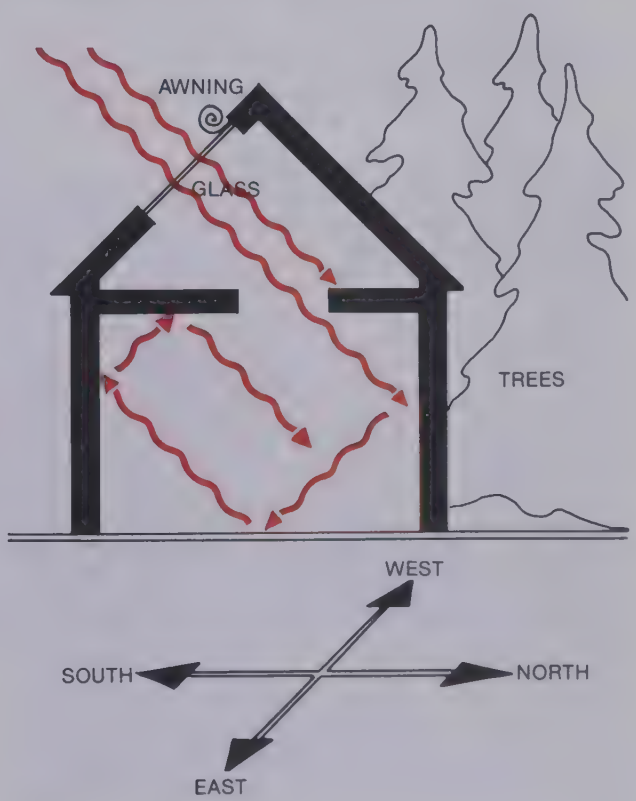
You may have noticed that the houses pictured here have evergreen trees on the north side. These trees do not lose all their leaves in the winter. They help protect the house from the cold north wind.

Deciduous trees are those that lose their leaves in the winter. Deciduous trees planted on the south side of the house will not block out very much of the winter sun. But they will shade the windows from the summer sun. In homes, the Greenhouse Effect is most unwelcome in the summer. You may also have noticed that the houses pictured here have awnings above the windows. The awnings are rolled up (or taken down) in the winter. In the summer, the awnings may be rolled out to shade the windows from the summer sun.

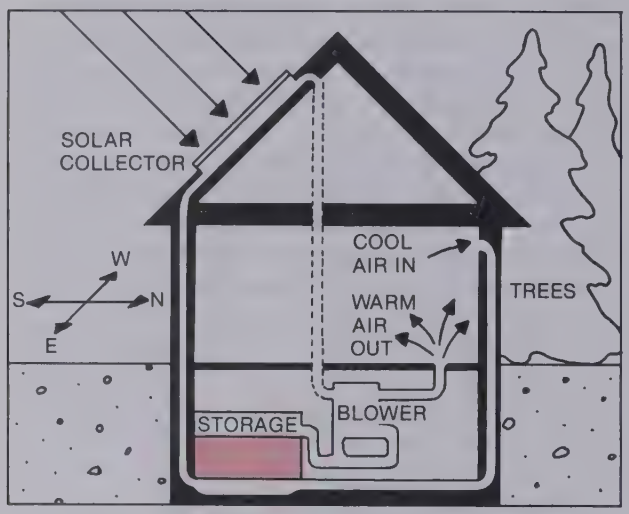
Windows on the east and west sides of a house do not have to be protected in this way. Ideally, there should be no windows on the north side of a house. Windows on the north side collect little of the sun's rays, but in the winter they provide poor insulation from the cold north wind.

Windows anywhere in a house allow heat to escape at night. Thick curtains help to keep heat in. Some houses have insulated shutters to go over the windows at night. Of course, insulating the walls and roof is necessary in a cold country such as Canada.





When the windows in a house are tilted to take advantage of the Greenhouse Effect, the walls and floor store energy during the day and release it at night. In a cold country such as Canada, the energy released as heat at night may not be enough to keep the home comfortable. Some homes have solar collectors to remedy this.



Find the solar collector in the drawing above. The solar collector has four parts: a case, some insulation, a sheet of glass, and some tubes.

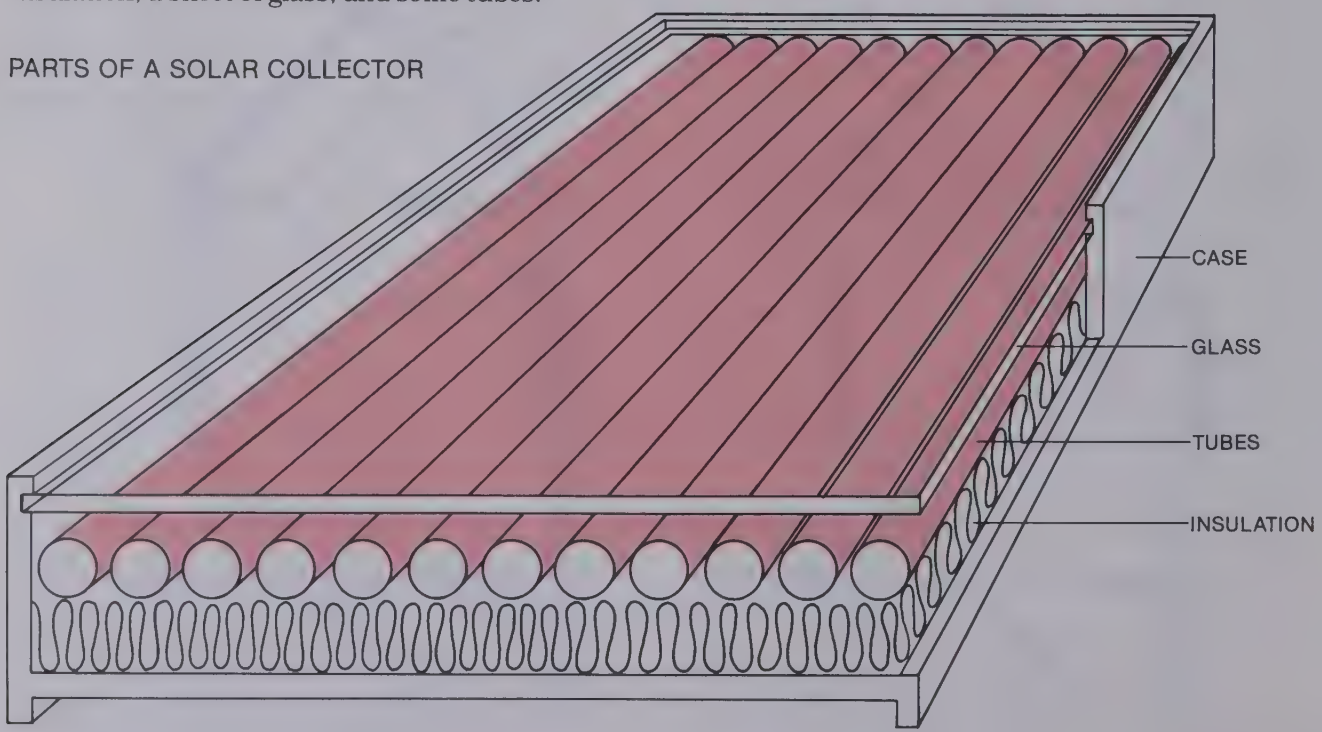
The solar collector uses the Greenhouse Effect to heat air inside the tubes. Look again at the first drawing on this page. Notice that the warm air goes to a storage tank. The storage tank may have air, water, or rocks inside. Look at your write-up for Experiment 3. Do you think it would be better to have air, water, or rocks in the storage tank? Why?

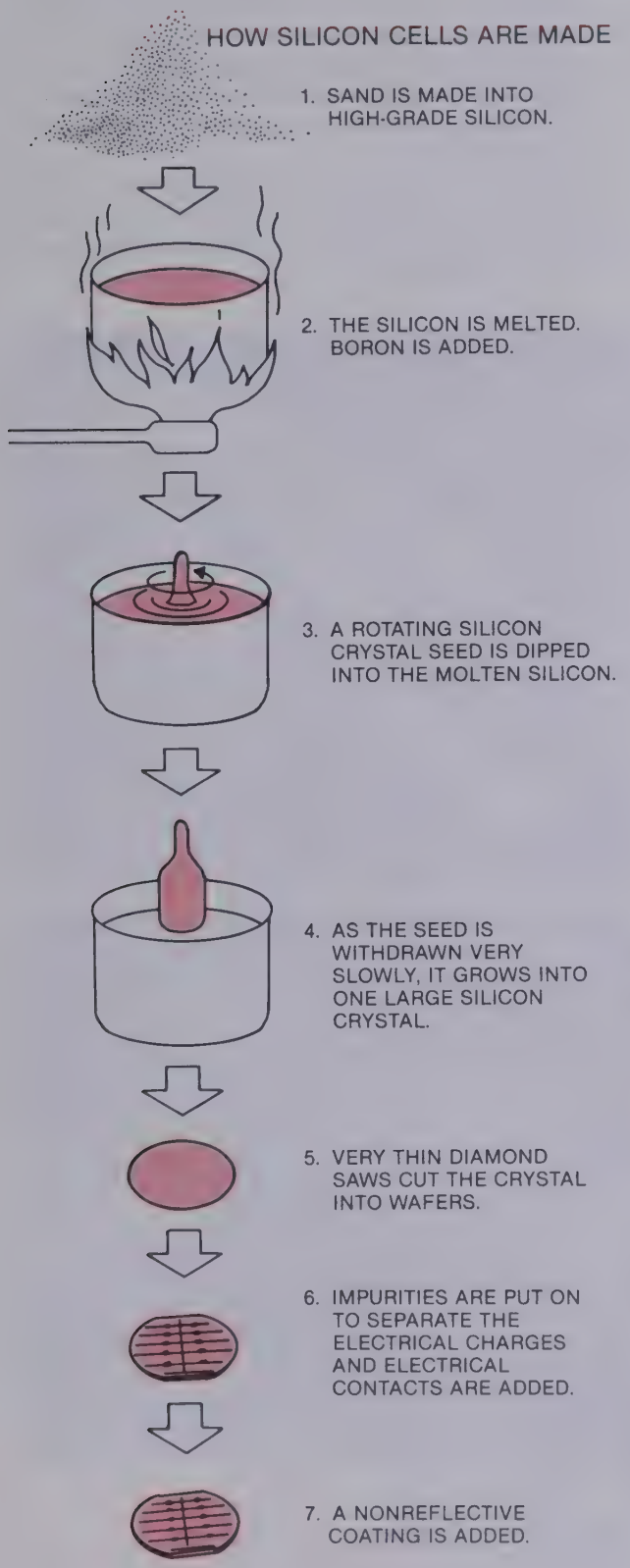
Look again at the first drawing on this page. A blower or fan sends the hot air from the storage tank out into the house. The blower is hooked up to a thermostat. The thermostat has a thermometer in it. When the temperature inside the house goes down, the thermostat turns the blower on. What happens then?

The cool air at the top of the house is drawn back into the storage tank to be heated again. If the air in the storage tank is not very warm, the blower can send air back up to the collector on the roof. (See the pipe drawn with dashed lines.)

Heating systems that store heat and release it on their own are called *passive* systems. Heating systems in which people can control how much heat is stored and how much is used are called *active* systems. Are the systems on pages 26 and 27 active or passive? Is the system on this page active or passive?

PARTS OF A SOLAR COLLECTOR




HOW SILICON CELLS ARE MADE
1. SAND IS MADE INTO HIGH-GRADE SILICON.
2. THE SILICON IS MELTED. BORON IS ADDED.
3. A ROTATING SILICON CRYSTAL SEED IS DIPPED INTO THE MOLTEN SILICON.
4. AS THE SEED IS WITHDRAWN VERY SLOWLY, IT GROWS INTO ONE LARGE SILICON CRYSTAL.
5. VERY THIN DIAMOND SAWS CUT THE CRYSTAL INTO WAFERS.
6. IMPURITIES ARE PUT ON TO SEPARATE THE ELECTRICAL CHARGES AND ELECTRICAL CONTACTS ARE ADDED.
7. A NONREFLECTIVE COATING IS ADDED.

Electricity from Solar Energy

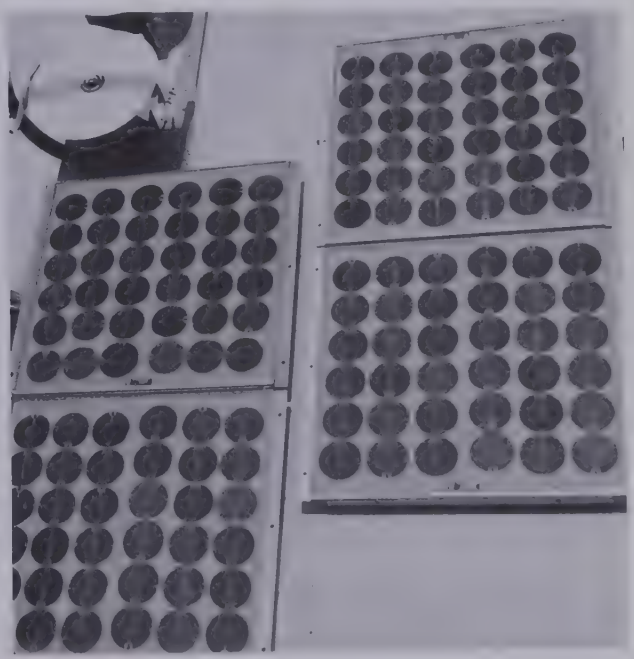
So far we have used the sun's energy mostly to heat buildings. The flat plate collector with air in its tubes provides twenty to fifty per cent of the heat required for many homes around the world. Some of those homes also have water heated by flat plate collectors.

However, other homes use a very different kind of collector called a photovoltaic collector.

> **photovoltaic,** fō″•to•vol•tā′•ik, *a.* [Gr. *phōs, phōtos,* light, and E. *volt,* a measure of electricity, from the Italian physicist Alessandro Volta, the discoverer of voltaism.] Generating electricity by allowing radiant energy to fall on the boundary between two different surfaces.

The photovoltaic collector uses very thin silicon cells. Silicon is a common substance. About one fourth of the earth's crust is silicon, much of it in the form of sand.

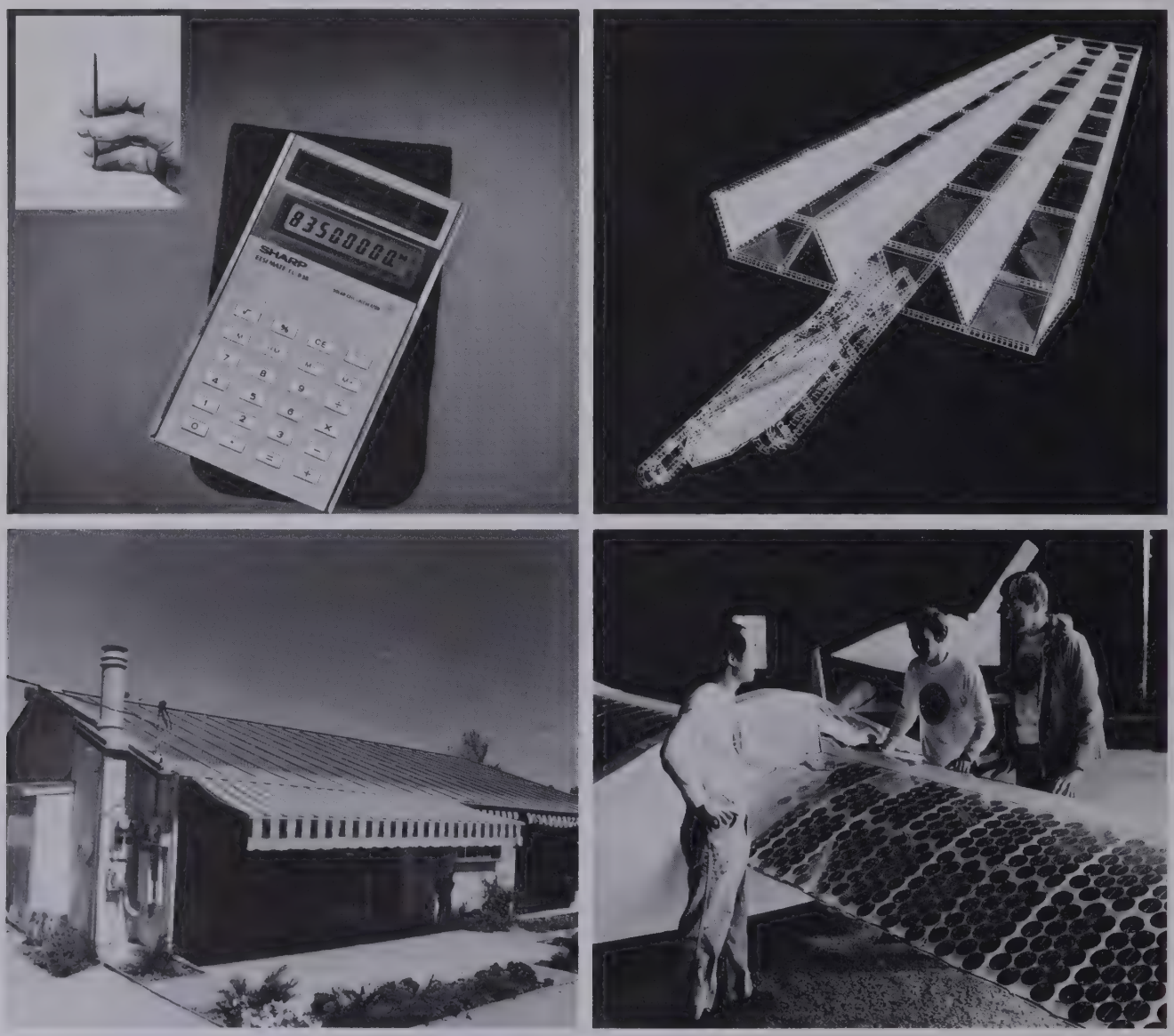
Silicon cells are very hard to make, so they are very expensive. However, in the future, as more and more of them are sold, and as we learn to make them more efficiently, silicon cells should become cheaper. You may have noticed that silicon cells are almost always round. The illustration on this page shows you why.



The first photovoltaic collectors were made in 1954 by Bell Laboratories. But in 1954, oil was cheap and silicon cells were very expensive. Oil has been getting more expensive ever since, while silicon cells have been getting cheaper.

Photovoltaic collectors are used in remote places where no power systems have been set up: in the ocean on buoys, on mountains for micro-wave communications systems, and away from cities and towns for railroad switches, pipelines, and radio telephones. Over 600 spacecraft have been equipped with photovoltaic collectors. Without them, the exploration of space would have had only limited success.

In one way or another, most of our energy comes from the sun. Using solar energy, we are now able to explore our solar system as well as provide part of the energy necessary for human life on earth.



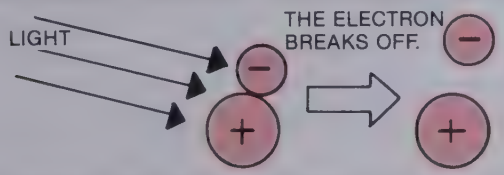
Anything that can be powered by electricity can use a photovoltaic collector with silicon cells.

5
Biomass Energy

What Is Photosynthesis?

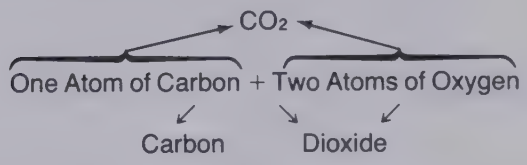
By reading and doing the experiments in Chapter 3, you learned some ways in which humans use the sun's energy. Try to think of at least three uses of the sun's energy you learned about in Chapter 4.

On pages 29 and 30, you learned about the photovoltaic collector, which is made up of silicon cells. Look again at the illustration on page 29 (How Silicon Cells Are Made). In step 6, impurities are put onto the silicon wafer. These impurities are made of metal. When light strikes the silicon, electrons are broken off from the silicon atoms.

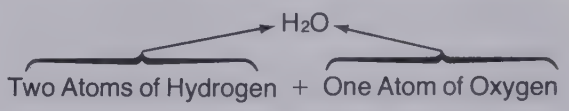


The electrons flow from the silicon into the metal and create a flow of electrons through the metal. This flow of electrons is called electricity.

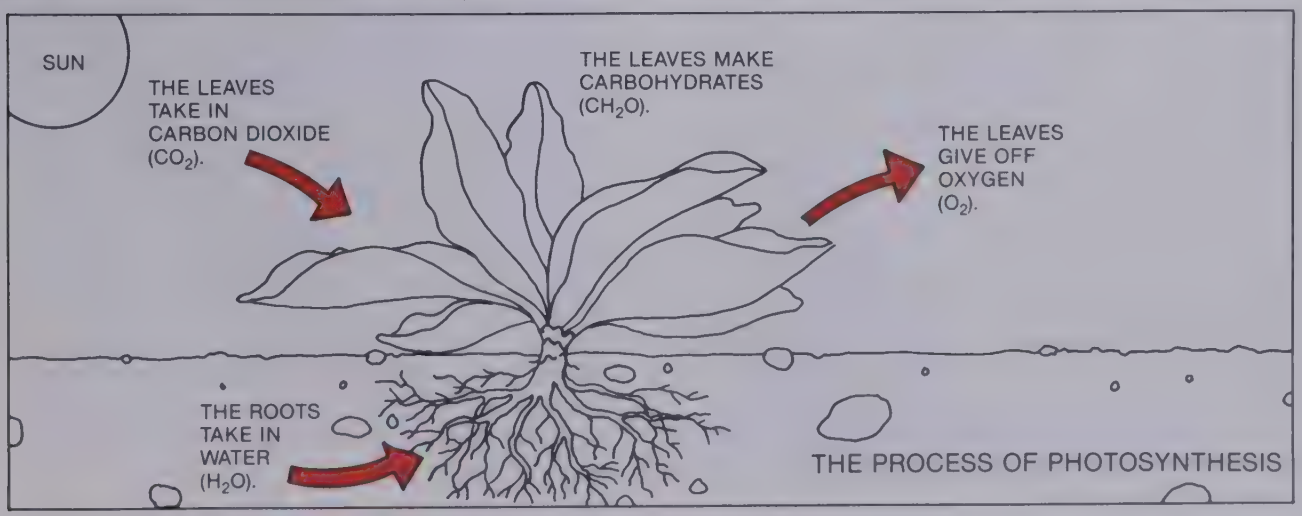
Something like this goes on in green plants. Plants use carbon dioxide and water to make chemical bonds



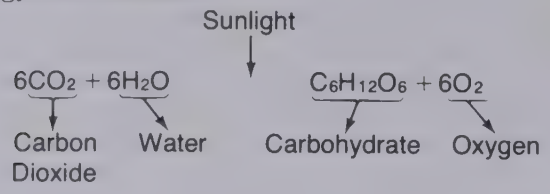
The chemical name for water is written like this:



Whenever two elements (such as carbon and oxygen or hydrogen and oxygen) are bonded together, a molecule is formed. Plants combine six molecules of CO_2 and six molecules of H_2O to form


SUN
THE LEAVES TAKE IN CARBON DIOXIDE (CO_2).
THE LEAVES MAKE CARBOHYDRATES (CH_2O).
THE LEAVES GIVE OFF OXYGEN (O_2).
THE ROOTS TAKE IN WATER (H_2O).
THE PROCESS OF PHOTOSYNTHESIS

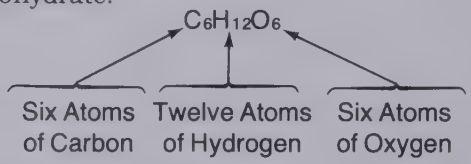
one molecule of carbohydrate. To do so, they use energy from the sun.



The leaves take in carbon dioxide. The roots take in water. The plant uses energy from the sun to break up the carbon dioxide and the water. When the molecules go back together, they form carbohydrates. Look at the word *carbohydrate*.

carbo-	**hydrate**
This tells you there is carbon in the new molecule.	This tells you there is water.

Look at the chemical name for the molecule of carbohydrate.



Carbohydrates are the basic foods of plants. They may be stored as starch or changed into sugars. The sugars may be

- combined with oxygen to make energy for chemical reactions within the plant.
- made into cellulose to build cell walls.
- combined with other molecules to make fats and proteins.

What Is Biomass?

Whenever molecules (such as carbon dioxide and water) are broken up and combined into new molecules, energy is required. Plants use energy from the sun to make carbohydrates from CO_2 and H_2O. This is called photosynthesis. Look up the word *photosynthesis* in a dictionary. What two words are combined to make this word?

You can tell that light is very important in photosynthesis because the word *photo* is included in the name. The energy from the sun's rays is used to break up and combine the molecules. This energy is not lost. It is stored in the new molecule and may later be regained by breaking up the molecule again. We gain the energy stored in carbohydrates when we eat and digest plants or burn plants to get heat.

The plant material we eat, digest, and burn is called biomass. Look at the word *biomass*.

bio—	**mass**
living	substance

We depend upon plants for their biomass and for the oxygen they give off.

All of our food comes from biomass. Some animals eat only plants. Some eat only other animals. Humans eat plants and animals. But the animals we eat consume plants, or other animals that consume plants. In the end, all food comes from the biomass of plants.

When we eat, we take in biomass. We use biomass to build the cells in our bodies and to provide energy for movement. In order to use biomass, we must break down the molecules in it. Breaking down molecules takes energy. Unlike plants, we cannot use energy directly from the sun to break down molecules. Instead, we oxidize our food.

oxid—	**ize**
This part of the word means *oxygen.*	This part of the word means *to combine with.*

We get our oxygen by breathing. We breathe in air, which has oxygen. In our lungs, the air is taken into our blood. The blood takes the oxygen to all parts of our bodies, where it is used in many chemical reactions. One of these is the oxidation of food. Oxidation in our bodies is a slow sort of burning.

When molecules are heated, their atoms move around more quickly. This makes it easier for them to break apart. When wood burns, it breaks down into ashes. When we oxidize our food, our bodies break it down in order to use the chemicals in it. When we cook our food, we use heat to break its molecules down and make it easier for our bodies to use. If we eat food raw, our bodies have to use more energy to break it down.

We get the oxygen to cook our food, and to oxidize it, from the oxygen plants give off at night. Without the sun, there would be no photosynthesis. Without photosynthesis, there would be no plants. Without plants, we would have no biomass to eat, no oxygen to breathe, and no oxygen to burn fuels.

6

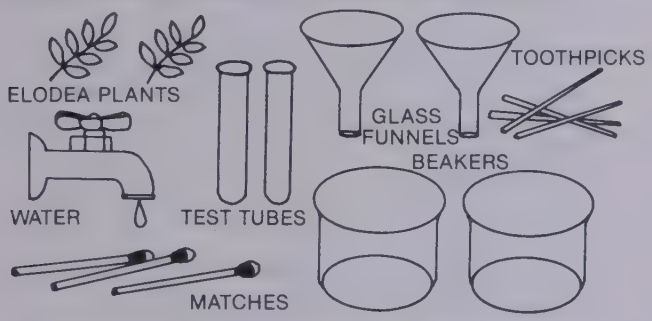
Demonstrating Biomass Energy

Activity

Experiment 4: What Does Sunlight Do to Plants?

HYPOTHESIS An aquatic plant (like the elodea plant) exposed to sunlight gives off oxygen.

MATERIALS You will need two aquatic plants (elodea plants), two glass funnels, two test tubes, two beakers, a supply of water, a lighter or matches, and a supply of wooden toothpicks.

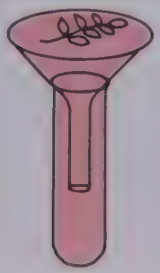


Elodea plants grow in water and are commonly used in aquariums. The funnels must be made of glass. Also, they must be smaller in diameter and shorter in height than the beakers.

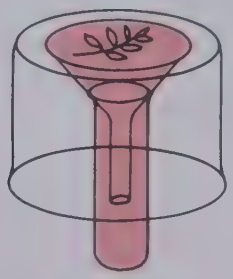
PROCEDURE Hold a test tube upright and place the small end of a funnel into it.

Place an elodea plant in the water.

Fill both test tube and funnel with water.



Place a beaker upside down over the funnel.



Hold the beaker and test tube tightly. Turn them over and set the beaker on the table. Fill the beaker with water. Make certain there are no bubbles in the beaker or the test tube.

Repeat the process with the other test tube, funnel, elodea plant, and beaker. You should now have two beakers: each with a test tube on a funnel, the funnel over the elodea plant, all inside a beaker. The test tube, funnel, and beaker should be filled with water. There should be no bubbles in either test tube.

Place one beaker in a place with *no light*. Place the other beaker in *bright sunlight*. Leave the beakers alone for one day.

One day later, place the beaker that was in sunlight on a table. Place the beaker that was in darkness nearby.

OBSERVATION Write a description of what appears to be in each test tube.

Take hold of the test tube from the beaker that was in sunlight. Lift it up slightly so that it clears the top of the funnel. *Do not lift it above the water line*. Slide it to one side. While the test tube is still under water, put your thumb firmly over its opening. Lift it out of the water and turn it over.

What happens next must be done quickly. Have a partner or your teacher help you. Have your partner (or your teacher) use the lighter or a match to light the end of a toothpick so that it burns like a match, blow the flame out, and, while it is still glowing, put the end of it into the test tube. *Your partner (or your teacher) should not let go of the toothpick*.

Write down what happens.

Take the test tube out of the beaker that was in darkness. Use the same method you used to remove the other test tube.

Have your partner (or your teacher) light a toothpick, blow the flame out, and put the glowing end into the test tube.

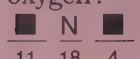
Write down what happens.

CONCLUSION The hypothesis is that an elodea plant exposed to sunlight gives off oxygen. In your conclusion, you will confirm or reject the hypothesis. Your conclusion is about the plant that was exposed to sunlight. What was in the test tube above that plant? Did it look like a liquid such as water or like a gas such as oxygen? What would you expect to happen when you put the glowing end of a toothpick into water? What would you expect to happen when you put the glowing end of a toothpick into pure oxygen? What actually happened in each case? What is your conclusion?

Below are six questions. Write the answer to each question. Number the letters in your answers as shown. To answer the riddle, match numbers with letters.

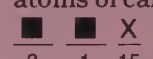
RIDDLE: If hydrogen burns and oxygen burns, why doesn't H_2O burn?

1. One molecule of water has how many atoms of oxygen?

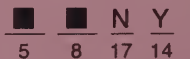


2. One molecule of water has how many atoms of hydrogen?

3. One carbohydrate molecule has how many atoms of carbon?



4. One carbohydrate molecule has how many atoms of hydrogen?

5. The sun is only one of 

stars.

6. Everything in nature has a

ANSWER:

Review of Experiment 4

1. List the steps of any experiment.
2. Write up Experiment 4 according to the steps you listed above.
3. The hypothesis of Experiment 4 is that an elodea plant exposed to sunlight gives off oxygen. This explains why you put one elodea plant in sunlight. Why was it necessary to put another plant in darkness?
4. Why was it important that the funnels be made of glass?
5. Why was it important that the funnels be smaller in diameter than the beakers?
6. Why was it important that the funnels be shorter in height than the beakers?
7. What were the test tubes for?
8. Why was it necessary to fill both the funnels and the test tubes with water?
9. Why was it important for there to be no bubbles in the beakers and test tubes?
10. After one day, what appeared to be in the test tube of the beaker that had been in darkness? Do you now think your first idea was right?
11. After one day, what appeared to be in the test tube of the beaker that had been in sunlight? Do you now think your first idea was right? Why or why not?
12. What happened when the glowing toothpick was put into the test tube of the beaker that had been in darkness? Give your reasons for what happened.
13. What happened when the glowing toothpick was put into the test tube of the beaker that had been in sunlight? What are your reasons for what happened?
14. In your conclusion did you confirm or reject the hypothesis? Why?

A Little Logic

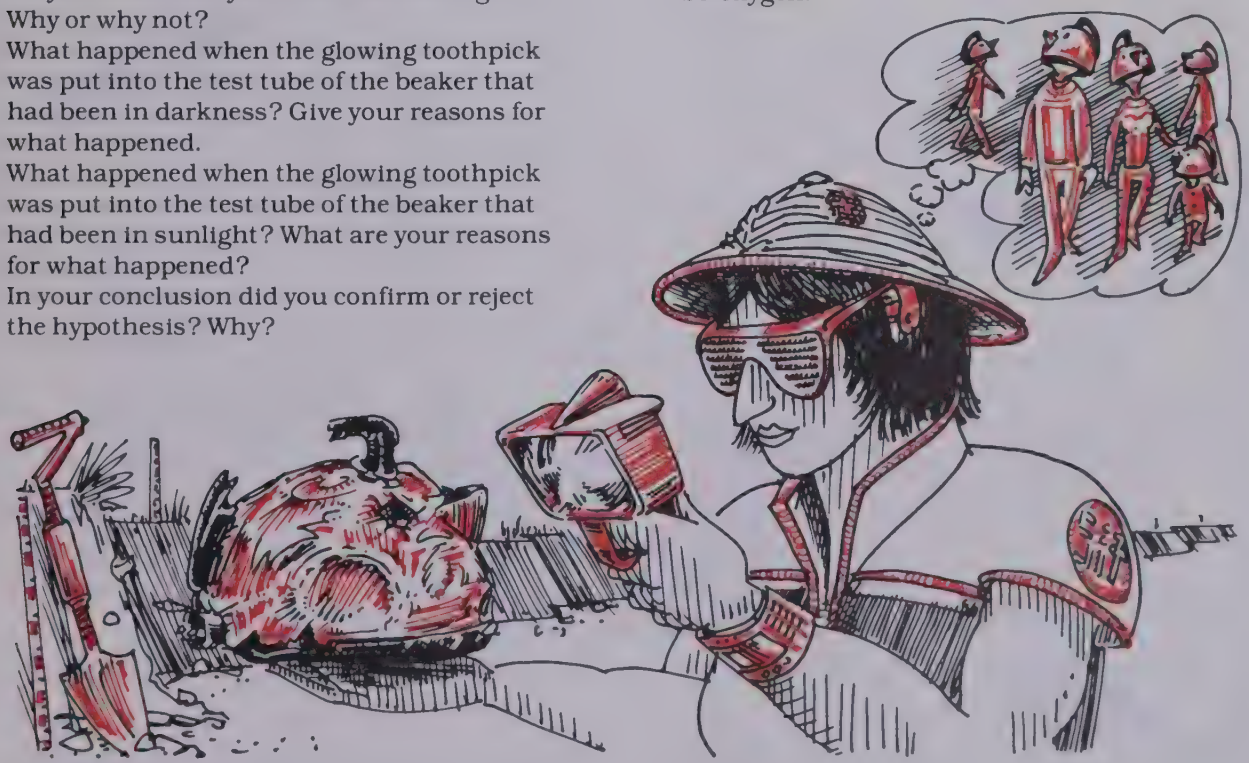
In the conclusion of Experiment 4, logic is very important. The experiment should test whether oxygen is produced by one of the plants. Someone might say, I did the experiment, but I have no idea whether oxygen was in either of the test tubes. What would you say to that person?

You could not really say, I think that was oxygen because it looked like oxygen. Oxygen is colorless and invisible.

You can not smell oxygen. You can not taste oxygen. And even if oxygen had a taste, *you should never taste chemicals to identify them*. That is a good way to get poisoned.

So you must use logic. Your reasoning might go like this.

a. Whatever was in the test tube was not liquid, not solid, and not plasma.
b. Therefore, the test tube had a gas in it.
c. Oxygen is a gas.
d. Oxygen helps wood to burn.
e. Whatever was in the test tube helped the wood to burn.
f. Therefore, whatever was in the test tube *could be* oxygen.



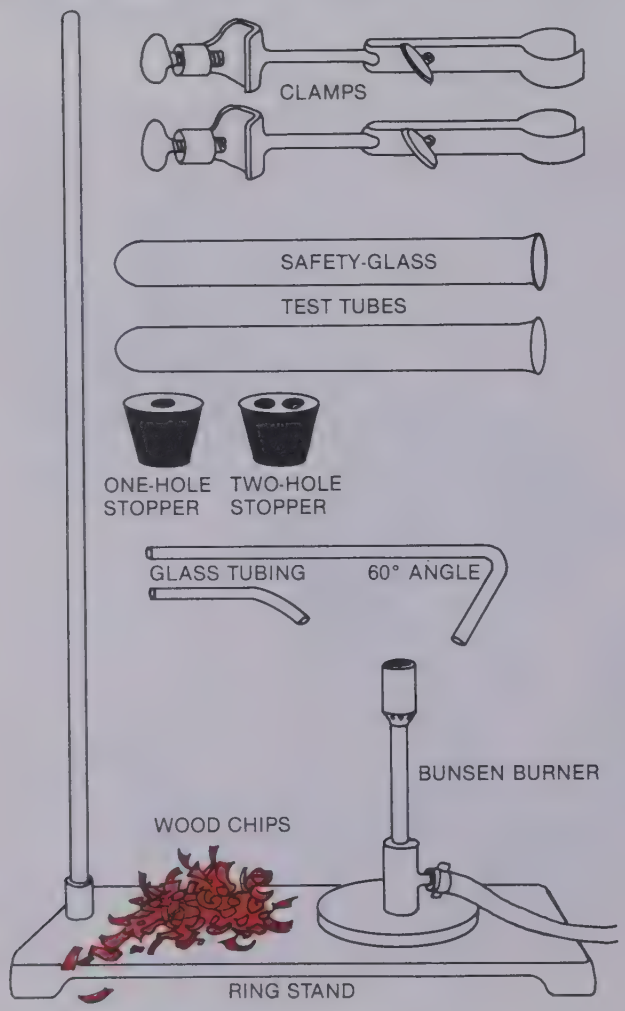
Activity

Experiment 5: What Happens to Wood When It Is Heated?

Your teacher will demonstrate this experiment. You are to act as an observer, following all steps closely.

HYPOTHESIS Distillation of wood results in charcoal, tar, water, alcohol, and methane gas. Do you know what the word *distillation* means? If you do not, look it up in a dictionary. The procedure in this experiment is also called dry distillation, or destructive distillation.

MATERIALS Your teacher will be using a small supply of wood chips, a Bunsen burner, a ring stand, two clamps, two safety-glass test tubes, a one-hole stopper, a two-hole stopper, a short piece of glass tubing (slightly bent), and a longer piece of glass tubing (bent at a 60° angle).



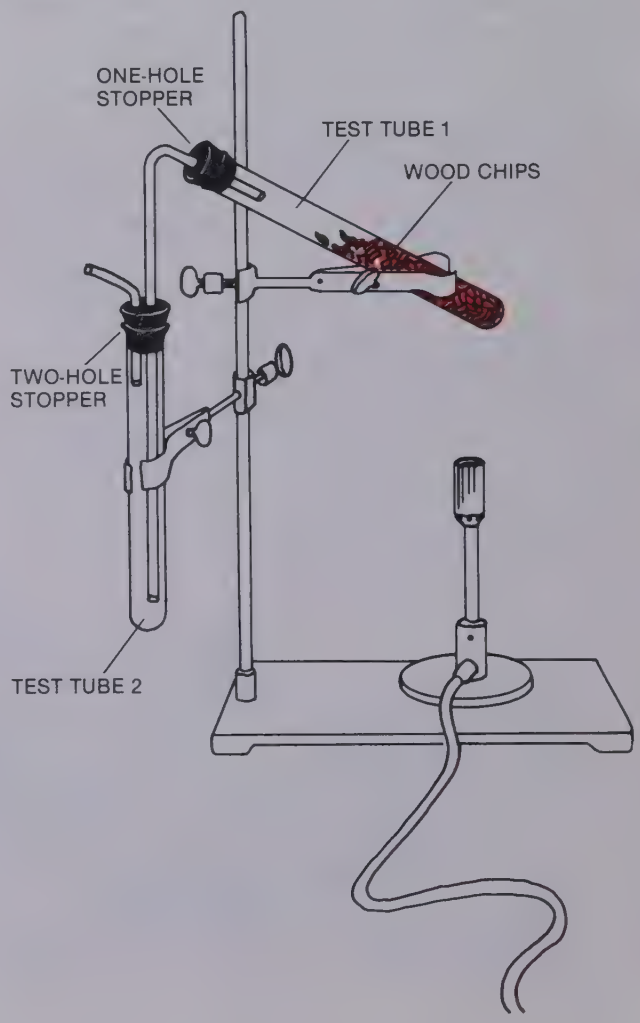
PROCEDURE The materials are to be set up by your teacher like those in the illustration below.

The bunsen burner is to be lit under Test Tube 1.

OBSERVATION Observe Test Tube 1. When something happens inside the test tube, write down exactly what you see.

After you have written down what happens in Test Tube 1, observe Test Tube 2. On a separate sheet of paper, write down what happens in Test Tube 2.

After you have written your observations for Test Tube 2, your teacher will light a match and place it at the opening of the glass tubing coming out of Test Tube 2. Write down what you observe. If nothing is happening, your teacher will wait until more material builds up in Test Tube 2 and try again.



Observe Test Tube 1 again. When the wood chips are gone, write down what you see in the test tube.

CONCLUSION In this experiment, the conclusion may not be obvious. You may have to use logic to reach your conclusion.

Look again at the hypothesis. Did your teacher distil the wood chips? If you do not know what the word *distillation* means, and you have not looked it up in a dictionary, do so now. If you decide that your teacher did *not* distil the wood chips, you can neither confirm nor reject the hypothesis because it has not been tested. If you decide that your teacher *did* distil the wood chips, you may go on with your conclusion.

The hypothesis says that distillation of wood results in five substances. On a sheet of paper, make a chart like the one below. Label your chart, *Conclusions of Experiment 5*.

Look again at your observations for Experiment 5 and try to decide where to put check marks on the chart you have made. If you have check marks in the *Undecided* column, use the information at the top of the next column.

- Charcoal is the material used in barbecues. It is solid. It is black. It burns. Artists sometimes use charcoal pencils.
- Tar is used to make asphalt highways and to patch roofs. Before it dries, it is a brownish-black, thick, sticky liquid.
- Water is the most common liquid on earth. Many plants and animals live in it. It is found in almost all living organisms.
- Alcohol is used to clean wounds. It burns easily. It is a colorless liquid that mixes readily with water. Alcohol evaporates at a lower temperature than does water.
- Methane gas has hydrogen and carbon in it. It has no color and no odor. It is *very* flammable.

Look again at your chart of conclusions. How many of the five substances on the chart can you now confirm? How many can you reject? About how many are you still undecided?

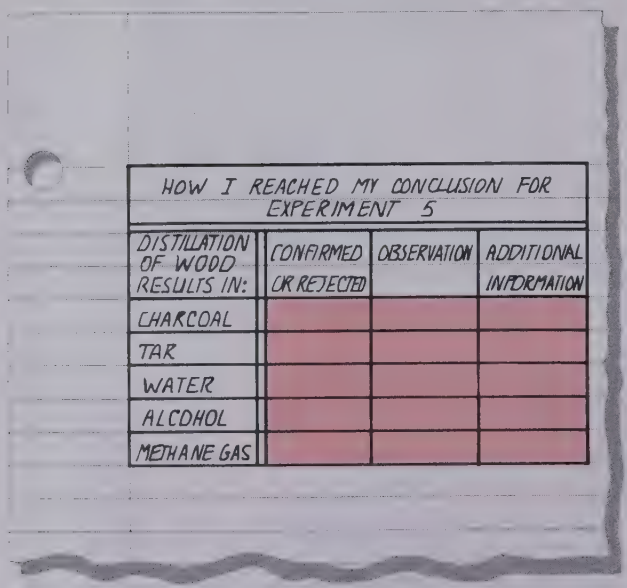
The method of science is experimentation. More often than not, experiments lead to further questions. Write up an experiment you might do to test any of the substances on the chart about which you are still undecided.

CONCLUSIONS OF EXPERIMENT 5

DISTILLATION OF WOOD RESULTS IN:	CONFIRMED	REJECTED	UNDECIDED
CHARCOAL			
TAR			
WATER			
ALCOHOL			
METHANE GAS			

Review of Experiment 5

1. List the steps of any experiment.
2. Write up Experiment 5 according to the steps you listed above.
3. Define *distillation*.
4. If you used glass tubing that was already bent, go on to number 5. If you bent your own tubing, write a step-by-step description of how to bend glass tubing. Assume you are writing a description for someone who has no idea how to do it. Be sure to stress safety.
5. What substance was produced in Test Tube 1?
6. What substances were in the bottom of Test Tube 2?
7. What substance came out of the glass tubing from Test Tube 2?
8. In this experiment, you should have reached five conclusions. It is very important in any experiment to state how you reached your conclusions. You had two sources of information: your observations, and the descriptions of each of the five substances at the top of the second column on page 37. You might like to make a chart like the one below showing how you reached your conclusions.



HOW I REACHED MY CONCLUSION FOR EXPERIMENT 5

DISTILLATION OF WOOD RESULTS IN:	CONFIRMED OR REJECTED	OBSERVATION	ADDITIONAL INFORMATION
CHARCOAL			
TAR			
WATER			
ALCOHOL			
METHANE GAS			

In the first column, write either *confirmed* or *rejected*. In the other columns, use check marks.

A Little Math

In the next experiment, you are asked to find out whether any energy is contained in a peanut. Energy is measured in joules. If you do not remember how much energy is represented by one joule, look again at column 1 of page 12. After you have done so, read the rest of this section carefully. Make sure you understand everything in this preview before going on to Experiment 6.

Preview of Experiment 6

Problem 1 4.2 J are required to raise the temperature of 1 mL of water 1°C. Room temperature is about 20°C. Body temperature is about 37°C. How many joules are required to raise the temperature of 1 mL of water from room temperature to body temperature?

Solution to Problem 1

Step 1 Set up an equation. Let J be the number of joules required. Let m be the mass of the water. Let T be the change in temperature.

$$J = m \times T \times 4.2$$

Step 2 Read the problem again and substitute values for m and T.

$$J = 1 \times (37 - 20) \times 4.2$$

Step 3 Do the arithmetic.

$$J = 1 \times (37 - 29) \times 4.2$$
$$J = 1 \times 17 \times 4.2$$
$$J = 71.4 \text{ J}$$

Step 4 Write your conclusion.

71.4 J of energy are required.

Problem 2 Room temperature is about 20°C. The boiling point of water is 100°C. How many joules are required to take 100 mL of water from room temperature to the boiling point?

Solution to Problem 2

Step 1 Set up your equation.

$J = m \times T \times 4.2$

Step 2 Substitute values for the mass (m) and the change in temperature (T).

$J = 100 \times (100 - 20) \times 4.2$

Step 3 Do the arithmetic.

$J = 100 \times (100 - 20) \times 4.2$

$J = 100 \times 80 \times 4.2$

$J = 33\,600$

Step 4 Write your conclusion.

33 600 J of energy are required.

Problem 3 How many joules are required to raise the temperature of 100 mL of water by 1°C?

Solution to Problem 3

Step 1 Set up your equation.

$J = m \times T \times 4.2$

Step 2 Substitute values.

$J = 100 \times 1 \times 4.2$

Step 3 Do the arithmetic.

$J = 100 \times 1 \times 4.2$

$J = 100 \times 4.2$

$J = 420$

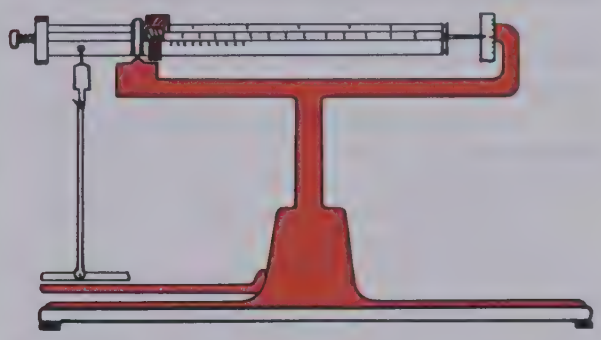
Step 4 Write your conclusion.

420 J of energy are required to raise 100 mL of water 1°C.

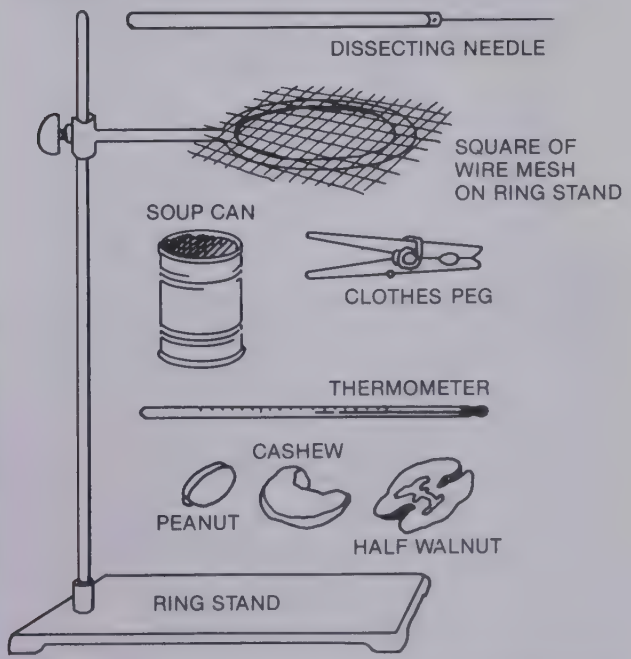
Activity

Experiment 6: Is There Energy in Biomass?

HYPOTHESIS Energy is stored in biomass.



MATERIALS You will need a set of scales, a ring stand, a square of wire mesh, a thermometer, a soup can, 100 mL of water, a peanut, ½ a walnut, a cashew, a dissecting needle with a long wooden handle, a clothes peg, and a lighter or some matches.



The square of wire mesh should be large enough to support the soup can. The soup can should have a capacity of more than 100 mL. If using matches, wooden matches are best for this experiment.

PROCEDURE Use the balance to find the mass of the peanut. Write this figure down.

Carefully put the tip of the dissecting needle into the peanut. (You will be holding the handle of the dissecting needle with the clothes peg.)

Put 100 mL of water into the soup can.

Place the square of wire mesh on the ring stand. Put the soup can on the wire mesh.

Put the thermometer into the soup can.

Take the thermometer out. Read and record the temperature of the water.

Set fire to the peanut with the lighter or matches. (If using matches, you may need to use more than one match.)

Hold the burning peanut about 2 cm from the bottom of the soup can.

Allow the peanut to burn until it stops burning on its own.

Put the thermometer into the soup can.

Take the thermometer out. Read and record the temperature of the water.

Let the peanut cool. Use the balance to find the peanut's mass. Write this figure down.

Rinse the soup can in room-temperature water.

Repeat the experiment using the walnut half first and then the cashew.

OBSERVATION While carrying out the procedure, you should have recorded twelve observations. You might like to make a chart like the one below and label it *Observations for Experiment 6.*

Record mass in grams. Record temperature in degrees Celsius.

CONCLUSION The hypothesis is that energy is stored in biomass. Did you use biomass in the experiment? If you are not sure, look again at the bottom half of the first column of page 32.

If you decided that you did use biomass, you must decide whether the experiment allows you to conclude that the biomass had energy stored in it. You know that energy is required to raise the temperature of water. If the nuts burned, gave off heat, and raised the temperature of the water, you should conclude that energy was stored in the nuts. If the nuts are biomass, you should conclude that energy is stored in biomass and confirm the hypothesis. If the nuts did not burn, and the temperature of the water was not raised, you should reject the hypothesis.

OBSERVATIONS FOR EXPERIMENT 6

	PEANUT	HALF-WALNUT	CASHEW
MASS OF NUT BEFORE BURNING			
MASS OF NUT AFTER BURNING			
TEMPERATURE OF WATER AT THE START			
TEMPERATURE OF WATER AT THE END			

Review of Experiment 6

1. List the steps of any experiment.
2. Write up Experiment 6 according to the steps you listed above.
3. Define *biomass*.
4. The experiment calls for 100 mL of water. How did you measure your water? Use the information below to name two other ways you could have measured the water.
   a. Graduated cylinders have measuring marks for liquids.
   b. Measuring cups have measuring marks for liquids.
   c. One millilitre of water has a mass of one gram.
   d. By law, the label of a soup can must tell the amount of the can's contents.
5. When biomass is burned, some of its mass is converted into heat energy. You can find out how much of the mass of each nut was converted to heat energy. Subtract the mass of the nut *after* burning from the mass of the nut *before* burning.
   a. How much of the mass of the peanut was converted to heat energy?
   b. How much of the mass of the walnut half was converted to heat energy?
   c. How much of the mass of the cashew was converted to heat energy?
6. True or false: If any of the mass of a nut is converted to heat energy, energy is stored in the nut.
7. You can find out how much the temperature of the water was raised by subtracting the temperature *at the start* from the temperature *at the end*. How much was the temperature of the water raised by the heat energy given off by the burning peanut? walnut half? cashew?
8. Heat energy can be measured in joules (J).
   a. How many joules of energy are required to raise the temperature of 1 mL of water 1°C? If you do not remember, look again at the bottom of the first column of page 39. If you do not really understand the math, read the preview of experiment 6 on pages 38 and 39 again. Take pencil and paper and work out the solutions yourself.
   b. You can find out how many joules of heat energy were given off by a burning nut. Multiply the number of degrees the temperature of the water was raised by the number of joules of energy required to raise the temperature of 1 mL of water 1°C. How many joules of energy were given off by the burning peanut? walnut half? cashew?

7
Using Biomass Energy

Fuel from Biomass

The word *fuel* has several meanings. Look up *fuel* in a dictionary. Try to understand each meaning of the word in terms of what you know about energy. The English word *fuel* comes from an Old French word *fouaille* which comes from the present French word *feu* (fire).

There are many types of fuel. Most of them are substances that burn in the presence of oxygen. As you know, wood will burn when set on fire in the presence of air. The simplest and oldest example of fuel from biomass is the burning of wood in fireplaces and stoves around the world.

Wood from sugar-maple trees is very good for burning. One cubic metre of sugar-maple wood can give off about eight terajoules (8 TJ) of heat energy. This is 8 000 000 000 000 J. Five blocks of sugar-maple wood this size can heat a typical house for a year. It would take about 3600 L of oil to do the same job.

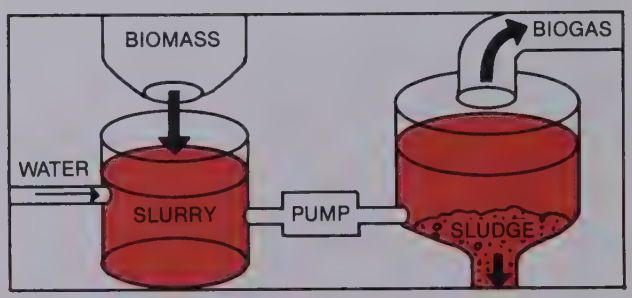
Fuel from Forest Wastes

Loggers usually take only large tree trunks, leaving limbs, tree tops, and smaller trees. As the price of energy rises, these may be harvested as well.

When the logs get to the mill, they are trimmed of their bark and commercial wood is produced. There is a lot of waste in this process. Some of it is used to make plywood and paper. Sometimes it is used by the mills to produce electricity or steam.

Waste from logging operations and from sawmills can also be collected and burned in industrial furnaces to produce heat energy. This waste can also be used to make biogas, methane, and methanol.

The biomass is shredded and combined with water to make slurry. The slurry is pumped into a large tank with no oxygen in it. After a while, the slurry begins to give off biogas.



The biogas that the slurry gives off is made up of:

- hydrogen sulfide (less than 1%),
- oxygen (less than 1%),
- carbon monoxide (less than 1%),
- nitrogen (less than 3%),

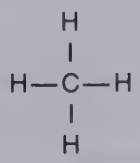
- hydrogen (1% to 10%),
- carbon dioxide (27% to 45%), and
- methane (54% to 70%).

Biogas is a fuel that can be burned to make steam to drive turbines to make electricity. Or, the methane can be taken out of biogas. Look at the chemical name for methane.

CH_4

One Atom of Carbon + Four Atoms of Hydrogen

Here is another way of showing methane.



You already know that hydrogen burns well. So you can imagine that methane does also. In fact, the natural gas that is burned to heat many homes is mostly methane. If methane is burned in air but not allowed to burn up completely, carbon is left over. This is used to make rubber and to make printer's ink black. The ink on this page has carbon in it.

Methanol can also be made from biogas. Look at the chemical name for methanol.

One Atom of Carbon + One Atom of Oxygen

CH_3OH

+ Four Atoms of Hydrogen

The biogas is treated, cleaned, put under pressure, and heated. The result is a liquid fuel that can be used to power cars. Methanol is also called methyl alcohol.

meth—	**yl**
From the Greek *methu*: wine.	From the Greek *hule*: wood.

Methanol is sometimes called wood alcohol.

Fuel from Urban Wastes

Cities produce a lot of garbage. The average Canadian throws away 2 kg of material a day. How much is this per year? How much is this for all of Canada per day? per year?

Most Canadians live in cities. Below is a breakdown of urban garbage.

URBAN GARBAGE BY PER CENT	
Glass containers	11%
Steel cans	7%
Aluminum cans	1%
Paper and cardboard containers	15%
Plastic	4%
Wood	1%
Newspapers, magazines, clothing	30%
Food	21%
Yard waste	5%
Miscellaneous waste	5%

Much of this material is organic. If the organic material is separated from the rest, it can be:

- burned to produce heat for homes or businesses,
- made into methane, or
- made into methanol.

This is an urban recycling station for biomass from garbage.

Fuel from Farm Wastes

Certain types of farms have large numbers of animals in a small space. Some have dairy cows; some have egg-laying chickens; some have broiler chickens; and some have pigs. Anywhere large numbers of animals are confined, their manure can be collected. Look again at the picture at the bottom of the second column of page 42. Manure can be fed into the slurry and used to produce biogas to heat farm buildings or methane to run tractors, trucks, and other kinds of engines needed on farms. After the biogas is taken out, sludge remains in the bottom of the tank. The sludge has very little odor and makes good fertilizer.

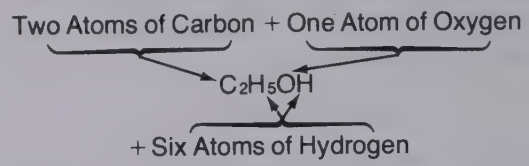
Farms also have plant wastes. There are pasture plants that have not been eaten, leftover feedstock in the spring of the year, and fruits, vegetables, or grains that are damaged and/or unsold. In Canada, waste from farm plants is about 17 000 000 t each year.

There are three kinds of biomass from plants.

BIOMASS FROM PLANTS	EXAMPLES
Cellulose	Wood, straw
Starch	Potatoes, grains
Sugar	Sugar beets

All three kinds of plant biomass can be used to make ethanol.

Ethanol is a more complicated chemical than methanol. Look at the chemical name for ethanol.



Ethanol is a colorless liquid made from the sugars in biomass. It is sometimes called ethyl alcohol. It burns easily and cleanly. Very high quality ethanol may be mixed with gasoline and used as a fuel for cars.

10% ethanol + 90% gasoline = gasohol

Changing 5% of the parts in an existing car will allow it to run on pure ethanol. Many cars in Brazil now use ethanol made from sugar cane for fuel.

PIESEL POWER

OKLAHOMA (OMNI)—One day last summer, Joel Curtis, a researcher on a Gold Kist peanut farm in Oklahoma, decided on a lark to put peanut oil in an old tractor. "It worked beautifully, as well as diesel fuel," Curtis said. "We ran it around the yard for about an hour. The emissions smelled like popcorn." He dubbed the fuel *piesel*.

Curtis's brainchild joins a growing number of experimental fuels using vegetable oil to replace petroleum. A key advantage is energy content. While alcohol fuels (methanol and ethanol) have only one half to two thirds the energy of petroleum, vegetable oils approximate—and sometimes even exceed—the power content of petroleum fuel.

Gold Kist is now blending a 30% soybean-oil mixture with diesel. Joseph Cox, Gold Kist's engineering director, said that after the oil is extracted, the protein meal is still left for food. Other candidate oils being examined are cottonseed, sunflower (which the Republic of South Africa is researching), linseed, and coconut. An Australian study says a typical farmer could satisfy all diesel needs with a tenth of his or her land.

The cost for vegetable oils today is 33¢ to 49¢/L and petroleum prices are rising. Some experts suggest recycling the millions of litres of used cooking oil now discarded by homes, schools, restaurants, and various other users of cooking oil.—*Stuart Diamond*

Alcohol fuels no longer small potatoes

(MACLEANS)—Alcohol fuels can be made from agricultural crops (ethanol) or from wood, coal, even municipal wastes, which yield methanol. The idea of using alcohol fuels to run vehicles is not new: Alexander Graham Bell and Thomas Edison both championed them, and Henry Ford actually built his Model T with an adjustable carburetor so that it would, if necessary, use pure alcohol.

However, it wasn't until the '70s that rising gasoline prices and a search for new agricultural markets combined to bring alcohol fuels back into focus. In the U.S., Nebraska took the lead in 1973 by offering motorists three cents off every gallon they purchased of fuels that were 10% agricultural ethanol. (It now offers 5½ cents.) Today the U.S. has more than 3000 gasohol-vending stations in 46 states.

Gasohol is being taken seriously in Saskatchewan. "We're looking at what we call distress grains," says Ken Johns of the provincial agricultural department, "which is wheat or barley touched by frost or with a high moisture content which makes it not marketable for human consumption." Saskatchewan produces an average of one million tonnes of distress grains a year, and Johns expects some of this to be used [soon] in farm-sized ethanol demonstration distilleries, and eventually in much larger commercial plants. "My feeling is that the potential is enormous," he says, pointing out that a huge and ready gasohol market exists south of the border.

The real beauty of gasohol, say its proponents, is that it can be derived from many things: not just grain and corn, but also potatoes, sugar beets, food processing, and brewery wastes. In Brazil, where it is made from sugar cane, gasohol is used in six million cars.

On Prince Edward Island, farmers have a problem with "cull" potatoes, spuds that aren't suitable for regular markets. These add up to about 15% of every year's crop, and farmers dispose of them by dumping, burying, or feeding them to livestock. "We could make ethanol on a small scale," says Andrew Wells of P.E.I.'s Institute of Man and Resources. "We're considering something that could be run by a farmer or a farmer and neighbors. The plant would burn wood, and the potato alcohol it produced would power the farm vehicles of participating farmers. P.E.I. hopes to construct a $20 000 pilot plant by fall to test the theory.—*David Folster*

Fuel Farms

One day all our reserves of oil will be gone. Long before that happens, liquid and gas fuels from biomass will become very valuable. In the near future, we will begin to see farms that grow fuel crops.

In the United States, many farms already grow corn that is used to make ethanol. In Brazil, 380 000 cars are now running on pure ethanol. This requires six hectares per car per year of sugar cane.

An advantage of this is that this is a recurring source of energy. We now know how to grow biomass for fuel year after year. The problem is that our bodies need fuel as well. Every hectare that is used to produce biomass for biogas, methane, methanol, or ethanol is one hectare that is not being used to grow food.

One solution is to make fuel only from biomass that is now going to waste. Another solution is to use land that is not being used to grow food. Solar energy can be used to grow bacteria in tanks in the desert. The bacteria could then be used as biomass to make fuel. After the fuel is made, the leftover biomass could be used as fertilizer.

Another solution is now being developed in Canada. On Durham Lake in Saskatchewan there is a 60-cm thick purple layer of microbes.

micr—
This comes from *micro*: small.

obe
This comes from *bios*: life.

There are two kinds of microbes in the layer. One is a purple bacterium that needs only sunlight and carbon dioxide to grow. The other microbe eats the purple bacterium and changes the biomass into oil. Under a microscope this microbe looks like a transparent bag stuffed with oil. This oil is natural diesel fuel, much like the peanut oil you read about on page 45.

These bacteria could be grown in large tanks on land that is not good for growing food.

In using biomass to make fuel, we take advantage of energy from the sun. Plants use photosynthesis to capture the sun's energy in chemical bonds. In doing so, they take in carbon dioxide and give off oxygen. Biomass fuels give off carbon dioxide and water when burned. Biomass fuels are better for the environment than petroleum fuels. But we must be very careful not to strip the earth of all its biomass to make fuel. Without plants growing wild around the world, we would not have oxygen to breathe. Without cultivated plants we would not have fuel for our bodies in the form of food.

8

Wind Energy

Thought Experiments

Some people think of science as being very precise with no nonsense involved. In some ways this is true. But fantasy has a place in science as well. The word *fantasy* comes from the Greek word *phantastikos*, which means producing mental images. Scientists use mental images to think up experiments. In fact, there is a special kind of experiment, called the *thought experiment*, that is never actually done in a laboratory, but only in one's mind. Albert Einstein used thought experiments when he was working on his theory of relativity. In one thought experiment, he imagined himself riding on a beam of light and asked himself questions about what he might experience.

Thought experiments do not replace experiments that are actually carried out. But sometimes it is not practical to do an experiment in a laboratory. That is when the thought experiment can be a useful tool.

This chapter is about wind. Wind seems very simple. After all it is just moving air, isn't it? But as a scientist, you may want to know why the air moves. Experiment 7 is a thought experiment that explores, with pictures, the question, why does air move? Experiment 7 asks a lot of questions and explores answers to those questions. While you are working through the experiment, keep a list of questions of your own.

Activity

Experiment 7: Why Does Air Move?

PURPOSE To try to discover why the wind blows.
MATERIALS You will need a pencil and some paper.
PROCEDURE The procedure in a thought experiment is in three steps. (In each of these steps you should make drawings, diagrams, or sketches. These do not have to be beautiful, but they should be simple and have a lot of labels.)

- Think of a very simple situation.
- Add as many details as you can.
- Change one thing in the situation.

Step 1 Think of a small town somewhere on the seashore. Call the town Airdale. It is just before dawn in a small park in the middle of town. The air is very still.

Step 2 Start adding details. You want to think about why the wind blows. Start with a cube of air sitting on the ground. Let's say that the cube of air is 1 m × 1 m × 1 m. Draw a picture of this cube.

Find out as much as you can about this cube of air. First, it has volume. What is its volume?

$$1\ m \times 1\ m \times 1\ m = 1\ m^3$$

It has a volume of one cubic metre (1 m^3). Add this information to the picture you have drawn.

Anything that has volume has mass. How much mass does this cube of air have? At this point in the experiment, you might have to go to the library or ask your teacher. Your question would be, how much mass does one cubic metre of air have? Since this is your first thought experiment, most facts—such as the fact that 1 m^3 of air has a mass of about 1 kg—will be given to you. Add this information to your drawing.

Now imagine a book sitting on a table. The book puts pressure on the table. The more mass the book has, the more pressure it puts on the table. In fact, anything sitting on a surface puts pressure on that surface. The cube of air you have drawn puts pressure on the ground. How much? If you were thinking up this experiment on your own, you would be off to the library again. Your question would be, how much pressure does a cube with a volume of 1 m^3 and a mass of 1 kg put on the ground? (A cube 1 m^3 with a mass of 1 kg puts a pressure of one pascal [1 Pa] on the ground.) Add this information to your drawing. Beside your cube write, pressure—1 Pa—and draw an arrow pointing down.

How much pressure is represented by one pascal? Try to think of something that has air with pressure. You know that the air in a bicycle tire has pressure because you have to work hard to pump it in. The air inside a bicycle tire has a pressure of about four hundred kilopascals (400 kPa). This is the same as four hundred thousand pascals (400 000 Pa). This is much more pressure than the cube of air sitting on the ground. How much more?

Anything that has mass and is putting pressure on the ground must have energy stored inside it. Again, you might be off to the library asking the question, how much energy is stored in a cubic metre of air that has a mass of 1 kg and 1 Pa of pressure? Going to the library and asking people questions are things that happen all the time in thought experiments. Most scientists work in teams and have lots of information stored in books and computers. The cube you have drawn is 1 m^3. (One pascal of pressure has stored energy of one joule per cubic metre.) Therefore, its stored energy is 1 J. Add this information to your drawing. If you have forgotten how much energy a joule represents, look again at page 12.

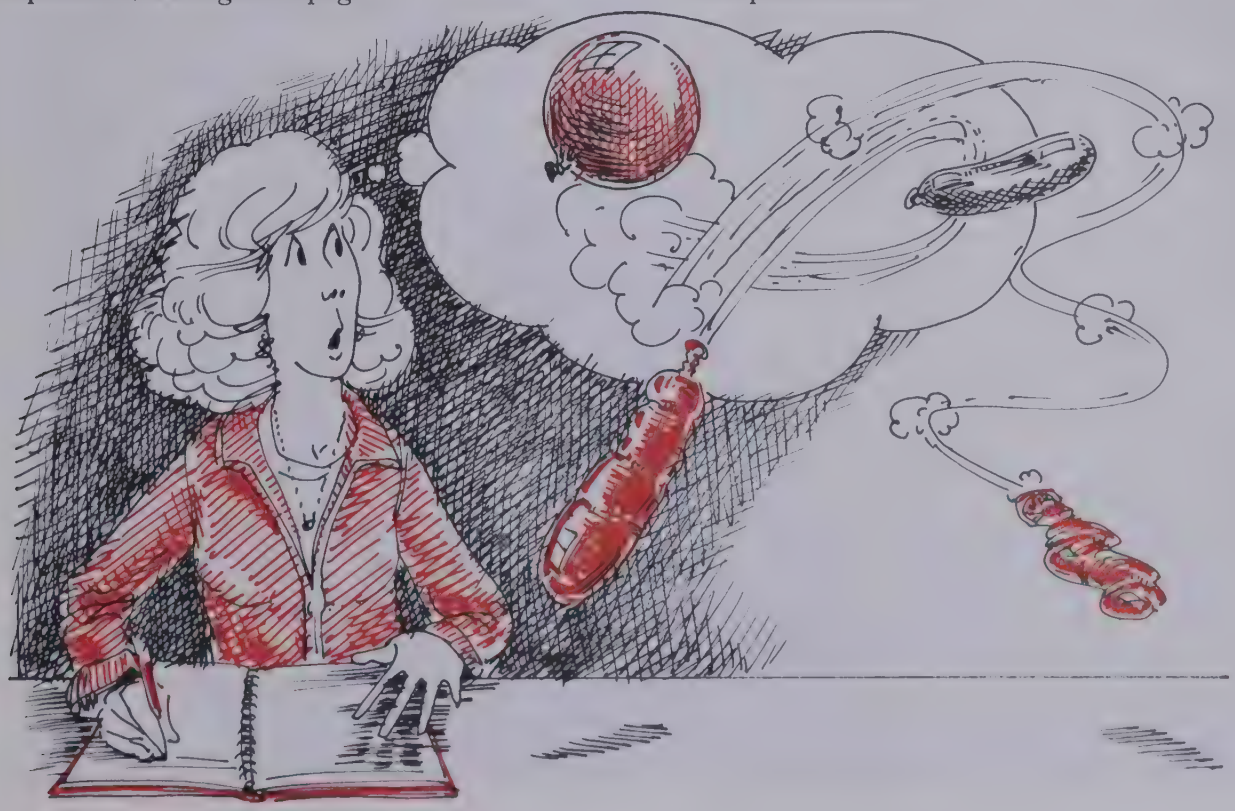
Step 3 Change one thing in the situation. So far, you have drawn a cube of air and added a lot of information to your drawing. Put this drawing aside and make another drawing of the cube sitting on the ground in the park in Airdale. This does not have to be a fancy drawing. Put arrows on your drawing to mark east and west.

Now change something. Say that the earth turns from west to east and dawn comes to Airdale. The sun is now shining on the ground below the cube of air.

OBSERVATION Observation is interesting in thought experiments because you have to imagine what you would observe.

First of all, the ground gets warm. It heats the air above it. You may know that hot air rises. The cube begins to float upward. Show this on your drawing. Put ① beside the cube on the ground. Draw a cube floating above it and put ② beside that.

When air is heated, it loses some of its pressure. The cube gets hotter and loses more of its pressure. It becomes a *low-pressure* area. Draw a third cube above the second one and label it ③—low-pressure area.



The cube keeps rising. But as it does so, the earth is still turning. The cube drifts west. Draw another cube higher and farther west. Label it ④.

The cube keeps rising. You may know that the higher up you go, the colder it gets. For instance, mountain tops are colder than beaches. As the cube rises, it starts to get cooler. Draw a cube higher and farther west. Label it ⑤—getting cooler.

The cube keeps rising and getting cooler. As it gets cooler, it gets back some of its pressure and becomes a *high-pressure* area. Draw a cube higher and farther west. Label it ⑥—high-pressure area.

You may know that cold air falls to the ground. Draw a cube lower and farther west. Label it ⑦—high-pressure area. Draw a cube almost at ground level to the west. Label it ⑧—high-pressure area.

Now, the area to the west of Airdale has air that is cold and has high pressure. Airdale's air is warm and has low pressure. What will happen?

Think of a bicycle tire. The air inside has high pressure. The air outside has low pressure.

If you open the valve of the bicycle tire, the high-pressure air rushes out toward the low-pressure air. The same thing happens in Airdale. The high-pressure air to the west of town rushes toward the low-pressure air in town. Show this on your drawing.

CONCLUSION Conclusions to thought experiments are different from conclusions to experiments that you can actually carry out. In a thought experiment, there is no hypothesis. Rather there is a *purpose*. What was the purpose of this experiment? What have you actually found out? Look back over the drawings you have made. Make a list of your conclusions.

Review of Experiment 7

1. List the steps of a normal experiment.
2. List the steps of a thought experiment. How does your list differ from the one you made above?
3. When would you use a thought experiment rather than the normal kind of experiment?
4. Write up Experiment 7 according to the steps you listed in number 2, above.
5. Define *fantasy*.
6. Name one scientist who used thought experiments.
7. What is the volume of the cube in the experiment? What would be the volume of a block 1 m × 1 m × 2 m?
8. What is the mass of the cube in the experiment? What would be the mass of a block 1 m × 1 m × 2 m?
9. How much pressure does the cube in the experiment put on the ground? Imagine another cube, just like the one in the experiment. One cube is sitting on top of the other. How much pressure do they put on the ground?
10. Imagine 100 000 cubes like the one in the experiment. They are stacked up into the sky. How much pressure do they put on the ground?
11. What is the pressure of the air inside a bicycle tire?
12. How much energy is stored in the cube of air in the experiment?
13. How much energy is stored in the air in a bicycle tire?
14. How much energy is represented by one joule?
15. On your drawing of Airdale, you drew arrows to mark east and west. Imagine that a person is standing with your drawing looking at Airdale. If west is on the left of your drawing, west is on the person's left. If west is on the right of your drawing, west is on the person's right.
    a. If west is on the left, is the person looking north or south?
    b. If west is on the right, is the person looking north or south?
16. Imagine someone saying, I think the earth turns from east to west. How would you convince that person that the earth turns from west to east?
17. Why does the air get warm when the sun shines?
18. Does hot air rise or fall?
19. Does hot air have high or low pressure?
20. As air rises, does it get hotter or colder?
21. Does cold air have high or low pressure?
22. Does cold air rise or fall?
23. What is wind?

9

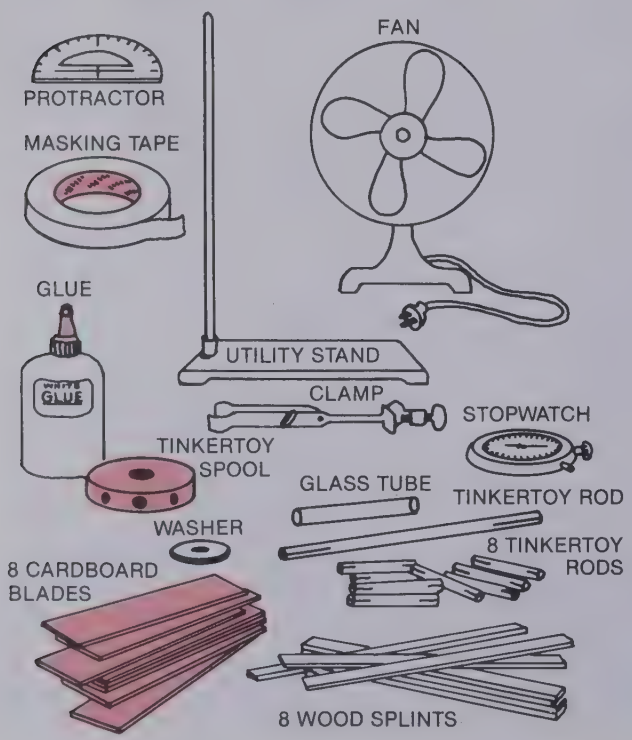
Demonstrating Wind Energy

Activity

Experiment 8: How Do Windmills Work?

HYPOTHESIS The angles of the blades of a windmill affect the speed at which the vanes of the windmill revolve.

MATERIALS You will need fast-drying glue (white resin), one Tinkertoy spool, one 13-cm Tinkertoy rod, eight 3-cm Tinkertoy rods, eight wood splints, eight cardboard blades (3 cm × 10 cm), one 8-cm glass tube, one washer, some masking tape, one utility clamp, one utility stand, one electric fan, and one stopwatch.

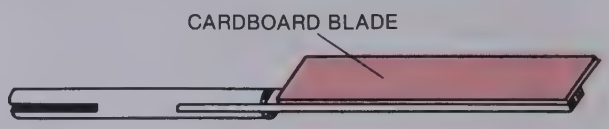


PROCEDURE You will probably need one session to make your windmill and another session to do your experiment.

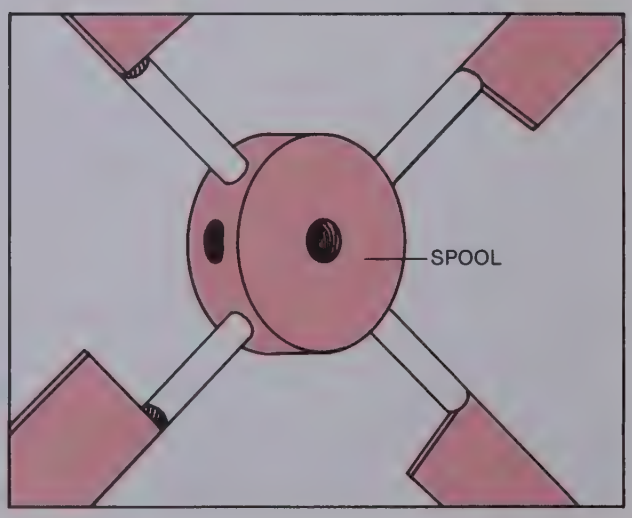
To make the windmill, follow these steps:

- Glue one wood splint into the end of each 3-cm rod. Allow the glue to dry.

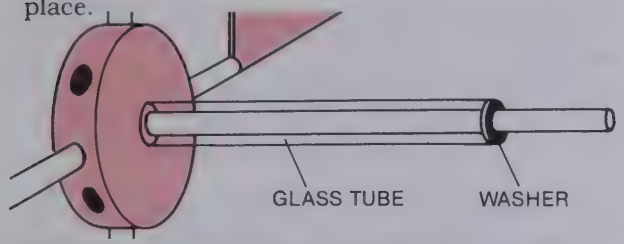
- Tape one cardboard blade onto each wood splint.



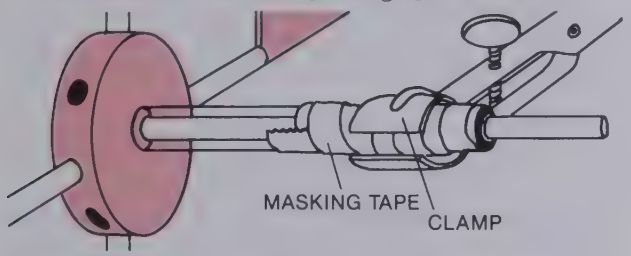
- Insert the rods with the blades into the spool.



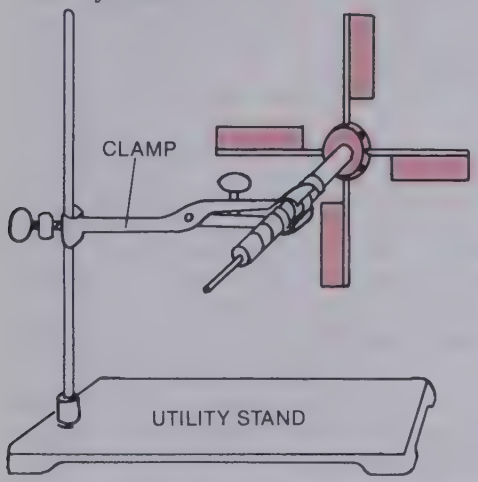
- Insert the 13-cm rod into the center hole of the spool. Place the glass tube over the rod and add a tight-fitting washer to hold the glass tube in place.



- Wrap some masking tape on the glass tube near the washer so the clamp can grip the tube.

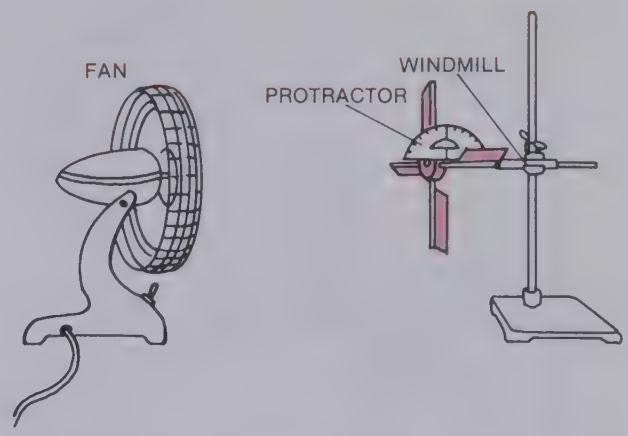


- Use the clamp to put the windmill onto the utility stand.



In doing this experiment, you will use a fan as a source of wind. The fan may be the kind that tilts up and down. It may have a different height than your windmill. Look again at your conclusions for Experiment 1. Decide what to do about the tilt of the fan, the height of the fan, and the height of the windmill. Then follow these steps:

- Stand facing the side of the windmill. The clamp should be on your right. The fan should be on your left. Hold a protractor up to one of the blades. The blade should stand up at 90°. Turn the rod to the right until the blade is at 45°.



Repeat for each of the other blades.

- Turn on the fan.
- Place the windmill close enough to the fan that it turns, but far enough away that you can count the number of turns a given blade makes each minute.
- Keep the windmill at this distance for the rest of the experiment.

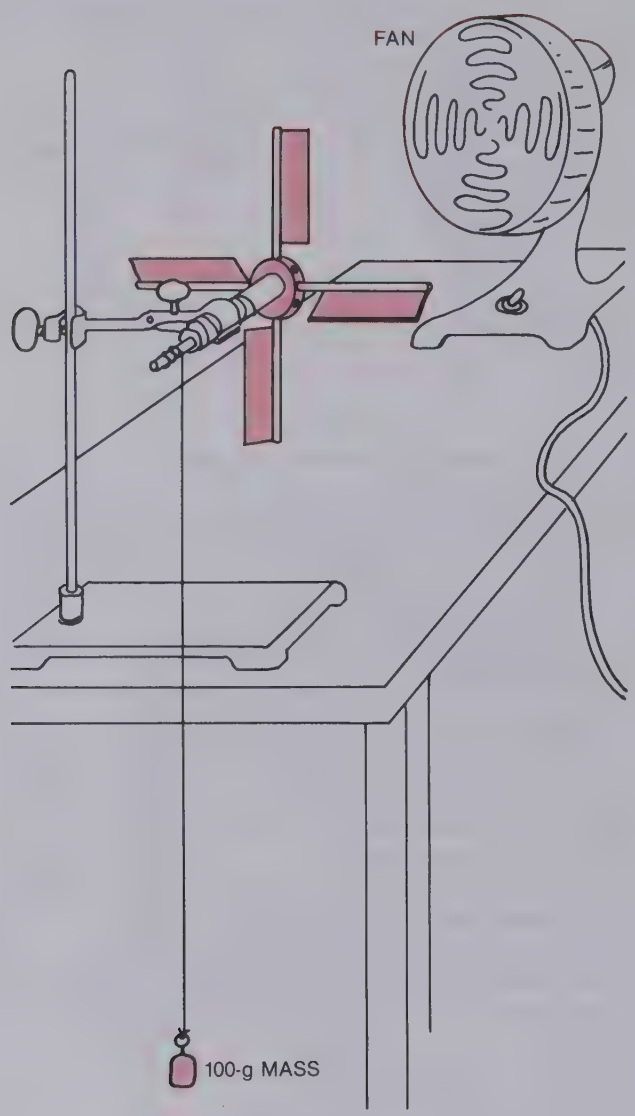
OBSERVATION Turn on the fan. After the windmill is turning well, concentrate on one blade. Count the number of times that blade goes around in one minute with the blades at an angle of 45°. Write down your observation.

Observe and record the number of times a blade goes around per minute with blades at the following angles: 60°, 75°, 90°, 30°, 15°, and 0°.

CONCLUSION In your conclusion you should confirm or reject the hypothesis and give your reasons.

Review of Experiment 8

1. List the steps of a normal experiment.
2. List the steps of a thought experiment.
3. Write a paragraph explaining the difference between a normal experiment and a thought experiment.
4. Write up Experiment 8. Include a chart of your observations.
5. Make the chart of your observations into a line graph. If you are not sure how to make a line graph, look again at the top of page 23. Label the vertical part of your graph, *Speed of Rotation in Revolutions Per Minute*. Label the horizontal part of your graph, *Angle of the Blades in Degrees*.



Activity

Experiment 9: How Can Wind Energy Be Stored?

HYPOTHESIS A windmill can be used to store energy.

MATERIALS You will need a model windmill such as the one you made in Experiment 8, an electric fan, a 1-m length of string, some masking tape, and a 100-g mass.

PROCEDURE Set up the fan and windmill as you had them for Experiment 8. Make sure the back of the windmill is at the edge of the table.

Tie one end of the string to the 100-g mass. Tie the other end to the rear of the shaft of the windmill. Put a piece of masking tape on the shaft over the string.

Check to see that the distance from the shaft to the 100-g mass is 1 m. If it is not, put books under the windmill or under the 100-g mass until the string has no slack in it. If you raise the height of the windmill, you must raise the height of the fan as well.

OBSERVATION Turn on the fan. Observe and record the amount of time the windmill takes to raise the 100-g mass 1 m.

Turn off the fan. Observe and record what happens.

Repeat the two steps above, four more times.

CONCLUSION In your conclusion you should confirm or reject the hypothesis. The following ideas may help you to reach your conclusion:

- You learned in Experiment 7 that anything that has mass has energy stored in it.
- Air has mass. Therefore, it has energy stored in it.
- The fan sets air in motion, causing wind energy.
- The energy something has because of its motion is called kinetic energy.
- When air turns a windmill, mechanical energy is caused.
- When the windmill raises the 100-g mass, potential energy is caused. Potential energy is a form of stored energy that exists because something has a certain height above base level. When the object is allowed to fall, the potential energy is released and can be turned back into mechanical energy.

Review of Experiment 9

1. List the steps of a normal experiment.
2. Write up Experiment 9 according to the steps you listed above.
3. In Experiments 8 and 9 you saw that moving air can cause the blades of a windmill to move. Look again at the bottom of the second column of page 54. What kind of energy does moving air have? What kind of energy do the moving blades of a windmill have? What kind of energy is caused when the 100-g mass is raised? What kind of energy is caused when the 100-g mass is allowed to fall?
4. In Experiment 9, you made five observations of the amount of time it took the windmill to raise the 100-g mass. You can find out the average time it took the windmill to raise the 100-g mass, by following these steps:
   - Make sure all the times are in seconds.
   - Add all the seconds together.
   - Divide your answer above by five. This is the average amount of time it took the windmill to lift the 100-g mass 1 m. What was the average time for your windmill?
5. Compare your average time with the average time of others. Is your average time higher or lower than others?
6. The windmill changed the energy from the moving air (kinetic energy) into other forms of energy. You can find out how much energy was generated.
   a. The mechanical energy can be measured in revolutions per second. One revolution per second is written 1 rev/s. How many revolutions per second were generated in the windmill?
   b. The potential energy can be measured in joules. On page 12, you learned about how much energy a joule represents. Now you can be more exact. It takes 1 J to lift 100 g one metre. How many joules of energy were generated in the windmill each time it lifted the 100-g mass?
7. Power is the rate at which energy is used. You can find out how much power was generated in the windmill, by following these steps:

   Power is energy divided by time.

   $$\text{power} = \frac{\text{energy}}{\text{time}}$$

   Look again at the energy you calculated in number 6*b*. Look again at the average time you calculated in number 4.
   - Substitute the amount of energy and the amount of time in the equation.

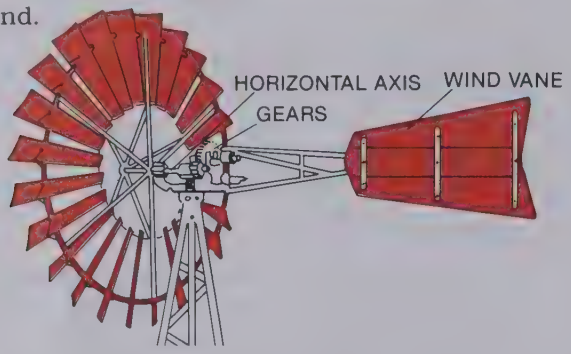
     $$\text{power} = \frac{\text{? joules}}{\text{? seconds}}$$

   - Divide the joules by the seconds. This will give you a number of watts. The watt (W) is a measure of power. How many watts did the windmill generate?

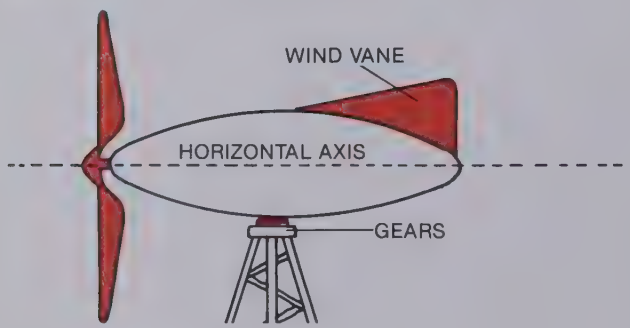
10
Using Wind Energy

Types of Windmills—Horizontal-axis

The oldest and best known kind of windmill is the *horizontal-axis* windmill. It has a set of blades mounted on a rod (or axis) that is parallel to the ground.



The windmill you made for Experiments 8 and 9 has a horizontal axis. In those experiments you positioned the source of wind directly in front of the windmill. Unfortunately, the wind can blow from any direction. Horizontal-axis windmills have wind vanes that turn the blades to face the wind. They also have gears that allow the windmill to turn around wherever the wind vane directs it. Below is a newer design of horizontal-axis windmill.



You may have noticed that the windmills shown on this page have different numbers of blades. Those with many blades are called multi-blade windmills. The windmill below is Dutch.

It is called a four-arm windmill. Other types are the modern three-blade and the high-speed two-blade.

Activity

Experiment 10: What Kind of Experiment Can You Create?

If you were building a windmill, how would you know how many blades to put on it? In Experiments 8 and 9 you worked with a model horizontal-axis windmill. In the Review of Experiment 9, questions 6 and 7, you learned how to calculate the amount of mechanical energy, potential energy, and power of the windmill you had built. Now you can put to use what you have learned.

This experiment is one that you design on your own. You may design several experiments or one experiment in several parts. You may design a thought experiment or a normal experiment. Here is the problem. For a horizontal-axis windmill, what is the best number of blades? length of blades? surface area of blades? shape of blades? angle of blades?

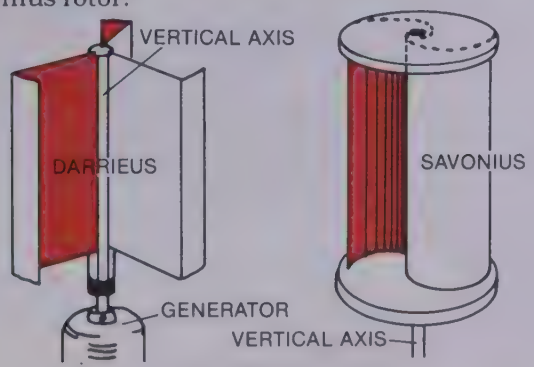
Review of Experiment 10

1. Did you design one experiment or several?
2. For each experiment you designed, was the experiment a thought experiment or a normal experiment?
3. For each experiment, what was your hypothesis (or purpose)?
4. For each experiment, what were your materials?
5. For each experiment, what was your procedure?

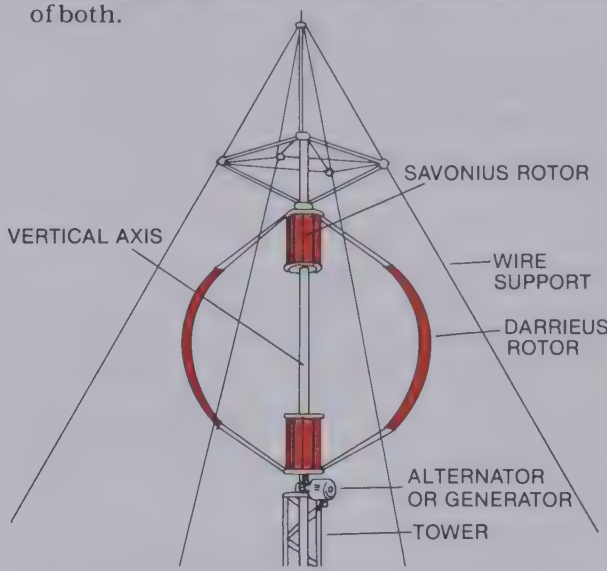
Types of Windmills—Vertical-axis

Another kind of windmill is the *vertical-axis* windmill. Below is a straight-bladed Darrieus rotor.

Another type of vertical-axis windmill is the Savonius rotor.



The Savonius rotor does not generate a lot of power. Compared to the Darrieus rotor, however, the Savonius is very easy to get going. Often, the two types of windmill are combined to make a Darrieus-Savonius rotor that has the advantages of both.



Vertical-axis windmills have two advantages over horizontal-axis windmills. First, the direction of the wind does not matter to a vertical-axis windmill. Horizontal-axis windmills have wind vanes. But sometimes winds come in gusts that come and go too quickly for the wind vane to swing the blades around. Second, a vertical shaft can be very long. If the windmill is producing electricity, the alternator or generator can be on the ground. It can be much bigger and it does not have to be made from light-mass expensive materials.

Making electricity is one of the main uses of modern windmills. A windmill that makes electricity has the following parts:

- The blades of the rotor catch the wind and the rotor spins.
- The rotor is mounted on a tower.
- There is either a generator or an alternator. A generator produces a *direct* current (DC). An alternator produces *alternating* current (AC). Direct current can be stored; alternating current cannot be stored. (If the windmill produces direct current, it must have an inverter to change the current to alternating current.)
- There is a voltage regulator to keep the flow of electricity steady.

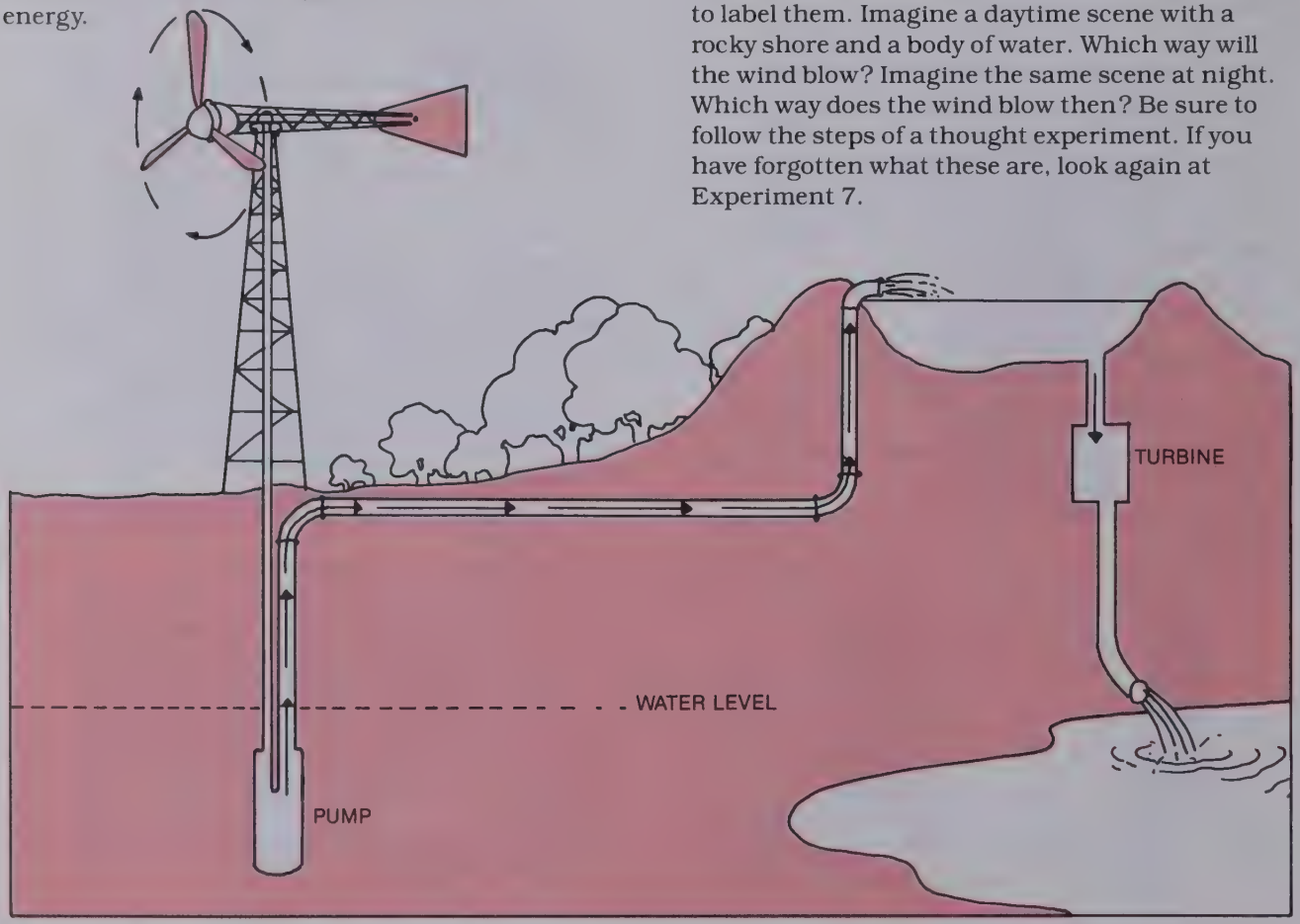
Types of Energy Storage

A windmill that makes electricity with an alternator cannot store the energy it creates. You would not want to be able to use the stove or turn on the lights only when the wind is blowing.

Windmills that have generators can store electricity in batteries like those used in cars. Larger batteries that hold more electricity are being developed all the time.

One good idea is to use the electricity from windmills to make hydrogen. If you do not remember how this can be done, look again at page 13.

Windmills can also turn the wind's kinetic energy into potential energy. If you do not remember what kinetic and potential energy are, look again at page 54. Windmills can be used to pump water uphill into storage tanks or reservoirs. From there, the water can be allowed to flow downhill through turbines to generate electricity. Potential energy is a type of stored energy.



Where Should Windmills Be Placed?

The answer is easy. Windmills should be placed where the wind blows. But where does the wind blow? Think back to Experiment 7. Wind blows from a high-pressure area to a low-pressure area. High- and low-pressure areas are created because the sun heats parts of the earth's surface at different rates. Why does this happen?

In Experiment 3, you saw that rock absorbs energy from the sun's rays at a rate different from that of water. Which absorbs more of the sun's energy in a given period of time, rock or water? When the sun is no longer shining, which gives off its heat more quickly, rock or water?

Activity

Experiment 11: Which Way Does the Wind Blow?

This is a thought experiment that you may do all on your own. Be sure to draw lots of diagrams and to label them. Imagine a daytime scene with a rocky shore and a body of water. Which way will the wind blow? Imagine the same scene at night. Which way does the wind blow then? Be sure to follow the steps of a thought experiment. If you have forgotten what these are, look again at Experiment 7.

Activity

Experiment 12: How Does Terrain Affect the Way the Wind Blows?

This is another thought experiment that you may do on your own. In Experiment 1, you learned that the angle of a source of energy affects the rate at which the vanes of a radiometer revolve. On page 25 you learned how greenhouse builders figure out what angle to make the south-facing glass of the greenhouse.

In Experiment 7, you learned that cool air has higher pressure and warm air has lower pressure. You also learned that high-pressure air rushes toward low-pressure air.

Get pencil and paper ready. Be ready to make lots of drawings. Be ready to ask questions and look up information in books. Do not stop doing this thought experiment until you are satisfied that you have learned something. Remember that whatever you decide you have learned should be something that could be tested by another experiment. Here is your problem.

Imagine some level ground and a mountain side. Which will the sun's rays heat faster? Which way will the winds blow? What will happen at night? Imagine two mountains with a valley inbetween. Which way will the winds blow in the day? at night?

Activity

How Does a Wind Gauge Measure the Amount of Wind?

Suppose you have done Experiments 11 and 12 and you think you know where to look for wind. How would you know how much wind is blowing? You could use an anemometer.

anemo—
From the Greek
anemo: wind

meter
From the Greek
metron: measure

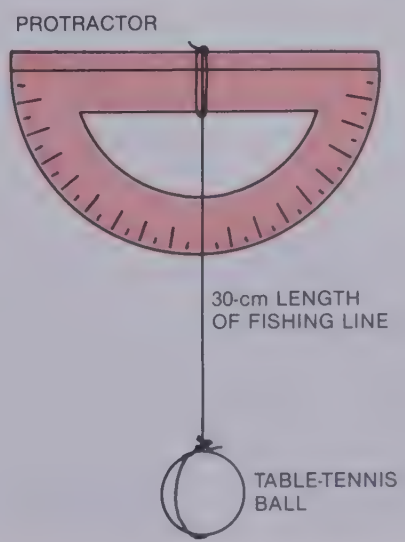
The illustration shows a cup-style anemometer.

Or, you could make an anemometer of your own.

You will need a large protractor, 40 cm of thin fishing line, a table-tennis ball (or golf practice ball), and some quick-drying glue.

Glue one end of the fishing line to the table-tennis ball. Wrap the other end around the center of the protractor until 30 cm of fishing line are hanging down. Put glue over the fishing line that is wrapped around the protractor.

Hold your anemometer curved side down, facing you. Your left side should be to the wind. Read the number of degrees marked by the fishing line. Find that number of degrees on the table on page 60.



THE BEAUFORT SCALE OF WINDS*

Beaufort Number	Name of Wind	Observable Features	Readings on Home-made Anemometer	Wind speed in Kilometres per Hour
0	Calm	Smoke rises vertically.		less than 1.5
1	Light air	Smoke drifts downwind. Wind does not move wind vane.		1.5 to 5.0
2	Light breeze	Wind felt on face; leaves rustle. Vane moved by wind.	90°-80°	5.0 to 10.0
3	Gentle breeze	Leaves and twigs in constant motion; wind extends light flag.	80°-70°	15.0 to 20.0
4	Moderate breeze	Raises dust and loose paper; small branches are moved.	70°-50°	20.0 to 30.0
5	Fresh breeze	Small trees in leaf begin to sway; crested wavelets form on inland waters.	50°-30°	30.0 to 40.0
6	Strong breeze	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.	30°-20°	40.0 to 50.0
7	Moderate gale	Whole trees in motion; inconvenience felt in walking against wind.	20°-0°	50.0 to 60.0
8	Fresh gale	Twigs break off trees; progress generally impeded.	Past this point, pack up your anemometer and go home.	60.0 to 75.0
9	Strong gale	Slight structural damage occurs (chimney pots and roof slate removed).		75.0 to 85.0
10	Whole gale	Seldom experienced inland; trees uprooted; considerable structural damage occurs.		85.0 to 100.0
11	Storm	Very rarely experienced; accompanied by widespread destruction.		100.0 to 120.0
12	Hurricane			Above 120.0

*After U.S. National Weather Service. Figures have been rounded.

Activity
How Can Windmill Sites Be Evaluated?

Suppose you have done your thought experiments, identified good possible windmill sites, and made wind-speed measurements at those sites. What wind speeds are acceptable for operating windmills? Here is a chart to help you evaluate windmill sites.

AVERAGE WIND SPEEDS	RATING
0–5.0 km/h	poor
5.0–10.0 km/h	marginal
10.0–15.0 km/h	fair
15.0–20.0 km/h	good
20.0 km/h or more	excellent

Notice that the wind speeds are average speeds. To calculate the average speed, you would visit the site as many times as possible during the year, add up all your readings and divide by the number of readings you took.

Here are some other things to consider.

- The rotor should be at least 10 m off the ground.
- The windmill should be well away from buildings, trees, and places where people walk.
- Certainly the rotor should not be on a building. Windmills vibrate a lot and are very noisy.

11

The Future of Renewable Energy Sources

All of the experiments and readings in this unit have shown you one thing: It is possible to get energy from renewable sources. Why then do we not make more use of renewables? Perhaps it is a situation similar to the discovery of the wheel in the New World. The wheel was a toy—looked upon as an amusing plaything because no one saw a practical use for it. Until the arrival of the Spaniards, the wheel was not used in all of North and South America.

One of the problems we face in using renewable sources of energy is cost. Our society is geared to the use of nonrenewables. Changes needed for us to make use of solar or wind power are very expensive, and, to date, not very effective. We have the knowledge and the equipment to use wood for heating our homes, but if everyone in a city the size of Halifax, for example, used wood for heating, the air would become so polluted with woodsmoke that it would be unfit to breathe.

What do you think? Are we just playing with renewables? Does the energy crisis have to become much worse before we begin to think seriously about using renewables? Are there any ways in which we can use renewables in a small way, to make a beginning? Is it worth making a beginning?

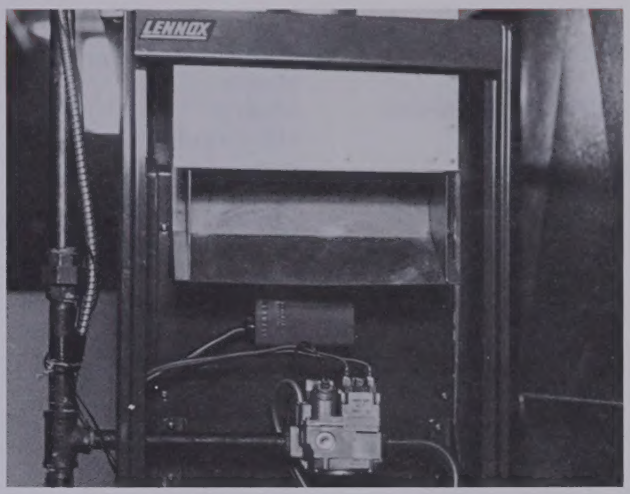
Activity

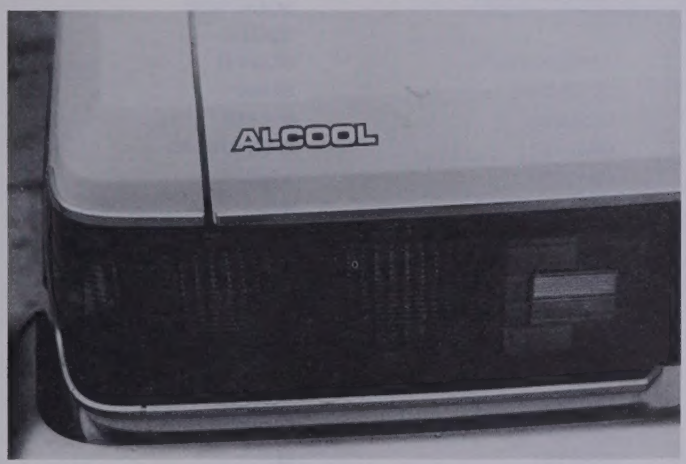
How Can the Use of Renewables Be Investigated?

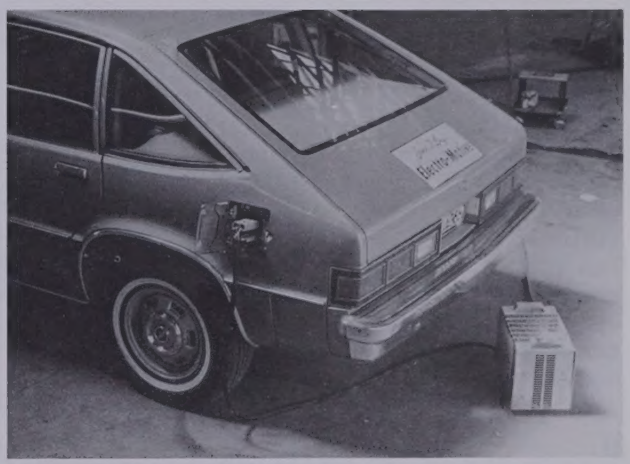
Perhaps you and your classmates could make a beginning by investigating the renewables being used now, in your community. You could find out whether or not they are proving to be better than the old ways of providing energy. You could find out what the difference is in cost, taking into account the expense of setting up the new system. If the use of renewables seems to be working well in one situation, you could investigate other situations in which it might also be advisable to use renewables. Perhaps you will then be in a position to make practical suggestions for new uses of renewables. You may find too, that there are places where renewables will not work. You should keep a list of these places and the reasons why it would be better not to use renewables.

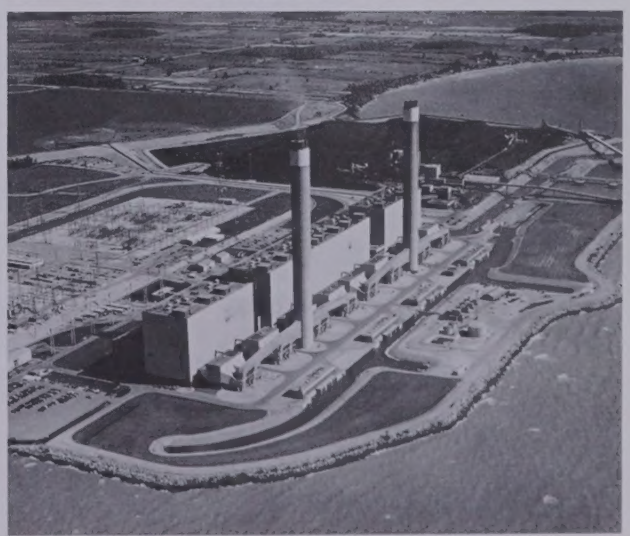
What Choices Will You Make?

Why Will You Make Them?









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Vocabulary

A
active
alcohol
alternating current
alternator
anemometer
angle
aquarium
average

B
bacterium
biogas
biomass
blade
boron
breeze

C
calm
carbohydrate
carbon
carbon dioxide
carbon monoxide
cellophane
cells
cellulose
charcoal
chromosphere
conclusion
confirm
convective zone
core

D
Darrieus rotor
Darrieus-Savonius rotor
dashed line
deciduous
digest
direct current
distillation
dotted line

E
electricity
electrons
elodea
ethanol
ethyl alcohol
evergreen
experiment
experimentation

F
fantasy
fat
four-arm windmill

G
gale
gas
gasohol
generate
generator
graduated cylinder
gust

H
helium
horizontal axis
hurricane
hydrogen
hydrogen sulfide
hypothesis

I
infrared
insulation
interior
inverter

J
joule

K
kilowatt
kilowatt hour
kinetic energy

L
latitude
liquid
logic

M
mass
materials
mechanical energy
megajoule
methane
methanol
methyl alcohol
microbe
molecule
multi-blade windmill

N
nitrogen
nuclei

O
observation
observer
opaque
oxidize
oxygen

P
pascal
passive
photosphere
photosynthesis
photovoltaic
plasma
potential energy
power
precise
pressure
procedure
propeller
protein
proton reaction
protractor

R
radiate
radiative
radiometer
recorder
reflect
reject
revolve
revolutions per second
rhodium

S
Savonius rotor
silicon
silicon cell
sludge
slurry
solar collector
solar energy
solid
solid line
splint
starch
store
storm
Styrofoam
sugar

T
tar
terajoule
thermometer
thermostat
tilt
transition zone
translucent

U
unstable helium

V
vertical axis
voltage regulator
volume

W
watt
wind energy
wind vane

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